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ISSUE 144
JULY 2023

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Everywhere you look, whether it's on our sister website **Space.com**, recent copies of **All About Space**, or on social media and other news outlets, the search for extraterrestrial life is a hot topic of discussion. In fact, it has been since I started out as a journalist in 2010. The major difference is that we have advanced somewhat in our hunt for organisms. That's something that has been echoed by one of my favourite comedians and physicist Ben Miller, famously known as one-half of comedy duo Armstrong and Miller, in this month's interview. Turn to page 24 for a thought-provoking read.

Also this month, we head over to the mysteriously known "Object X", a star (or so we think!) in the Triangulum Galaxy that only really shines brightly in infrared. Its existence was announced quite some time ago now, and this issue our reporter Colin Stuart has uncovered several of its secrets from the researchers continuing to puzzle over this object's unusual characteristics.

Enjoy the issue, and keep in touch!

GEMMA LAVENDER
Editor

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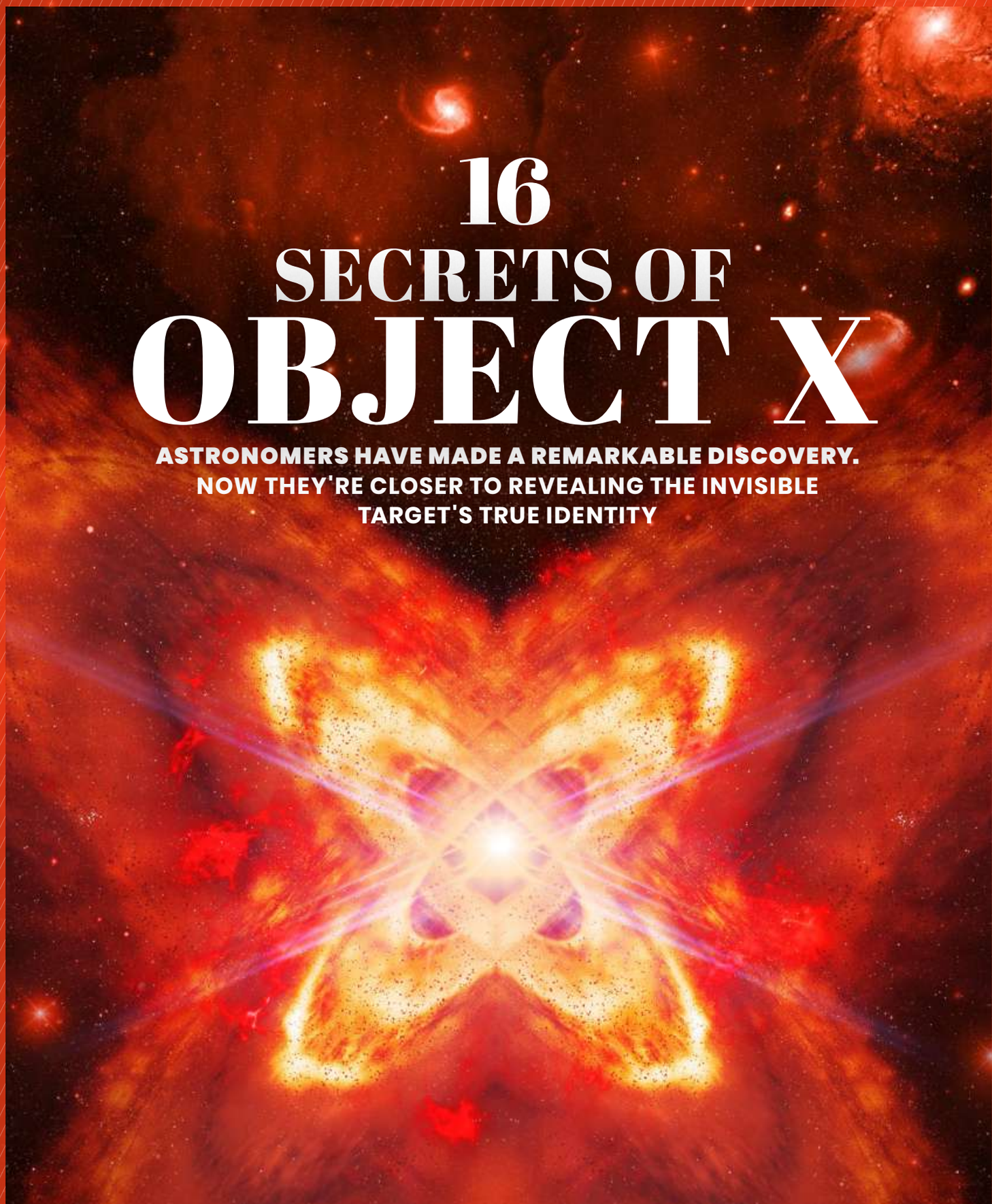
INSIDE



16 SECRETS OF OBJECT X

ASTRONOMERS HAVE MADE A REMARKABLE DISCOVERY. NOW THEY'RE CLOSER TO REVEALING THE INVISIBLE TARGET'S TRUE IDENTITY

LAUNCHPAD

06 News from around the universe

FOCUS ON

23 Pentagon has "no credible evidence" of aliens or UFOs

FUTURE TECH

24 Pluto orbiter and lander
A US consultancy and NASA are working on an engine that could open up the Solar System

INTERVIEW

26 Ben Miller
The comedian, actor and science enthusiast talks about the hunt for extraterrestrial life

FOCUS ON

30 Signs of water on the Red Planet

32 Future of Virgin Orbit
With the unravelling of Virgin Orbit, what does the future hold for the UK's space industry?

INSTANT EXPERT

38 How are aurorae formed on other planets?
Earth's northern and southern lights are caused when solar wind affects the atmosphere – and this can happen on other planets too

42 Mysterious space shapes
Humans keep finding patterns among the stars, helping us shed new light on astronomical wonders

FOCUS ON

50 Quakes could 'smooth out' the surfaces of moons

52 Heroes of space
Six men and women who made groundbreaking contributions to our understanding of the universe

FOCUS ON

58 Discovered: closest star-shredding black hole to Earth ever seen

60 Hunting for interstellar planets
Space is thought to be filled with worlds wandering alone without a star, but could such loners ever shelter life?

68 Where did Earth get its water from?
Two new studies have taken researchers closer to discovering the source of Earth's water

FOCUS ON

74 Uranus' moons may have salty oceans

76 Ask Space
Your questions answered by our panel of experts

STARGAZER

80 What's in the sky?

82 Planetarium

84 Month's planets

86 Moon tour

87 Naked eye & binocular targets

88 Deep sky challenge

90 The Northern Hemisphere

92 Review

96 In the shops

WIN!
OLIVON T-900 SPOTTING SCOPE AND TR154-11 TRIPOD
15

7 April 2023

Wreckage of a titanic cosmic explosion

A new image from the James Webb Space Telescope shows in stunning detail the wreckage of a cataclysmic supernova explosion. The supernova remnant, known as Cassiopeia A (Cas A), formed about 340 years ago from our perspective here on Earth. This makes the ten-light-year-wide Cas A one of the youngest clouds of supernova wreckage we know of. With images like this, scientists can perform 'cosmic forensics' to better understand what happens when stars die. Material expelled by supernovae such as this goes on to disperse throughout galaxies and becomes the building blocks for the next generation of stars and planets. Around 4.6 billion years ago, such a process helped forge the Sun and the planets of our own Solar System and paved the way for living things, supplying elements like the calcium in our bones and the iron in our blood.

Cas A can provide a window into the very early stages of this process, and for this reason the object – located 11,000 light years from Earth in Cassiopeia – has been widely studied by astronomers with ground and space-based telescopes. "Cas A represents our best opportunity to look at the debris field of an exploded star and run a kind of stellar autopsy to understand what type of star was there beforehand and how that star exploded," Danny Milisavljevic of Purdue University in Indiana, principal investigator of the Webb program that captured the new observations, said.

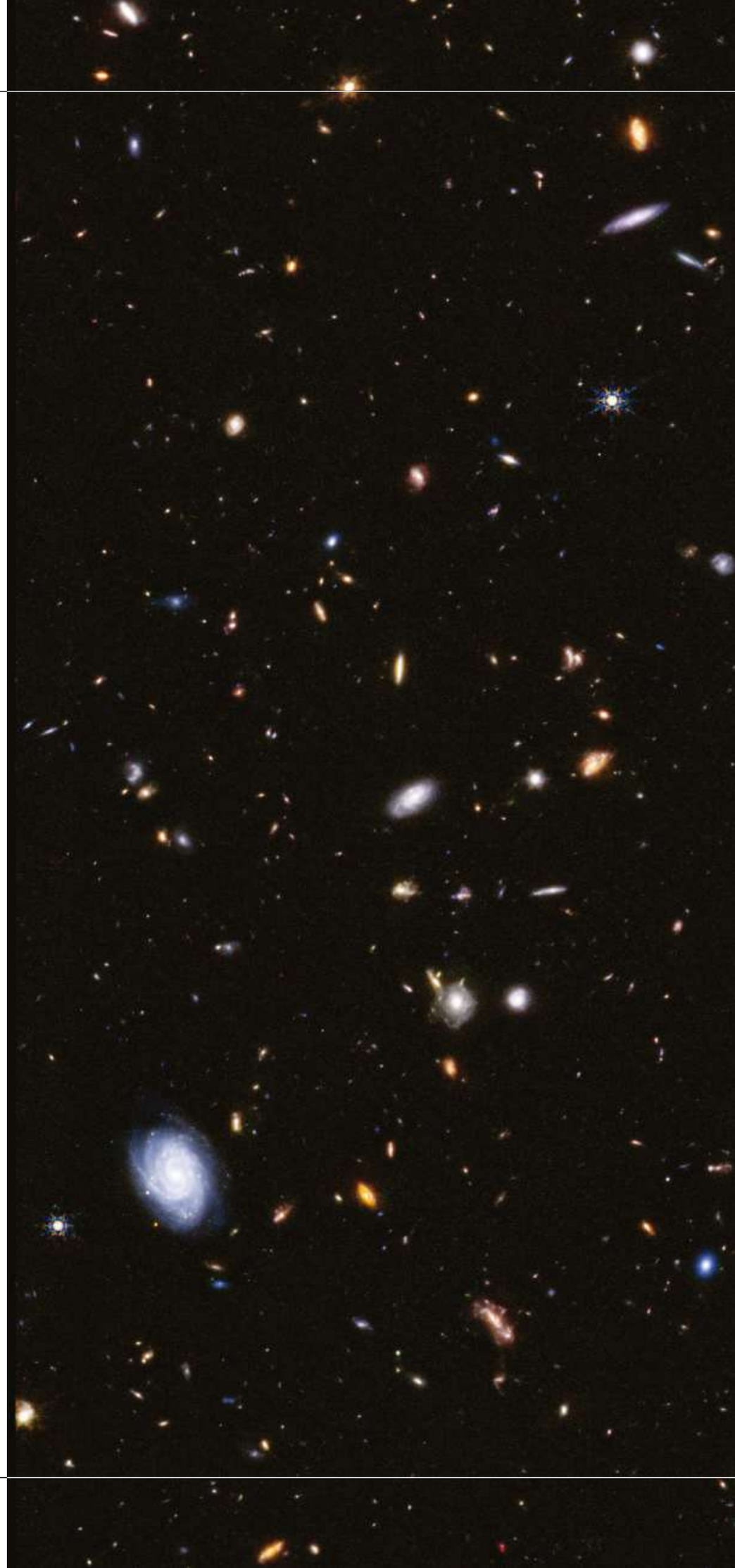
© NASA

13 April 2023

Ultra Deep Field

NASA's James Webb Space Telescope has turned its sharp eyes on a distant patch of sky made famous by its predecessor. A newly released Webb photo captures the Hubble Ultra Deep Field (HUDF), a faraway region in the southern constellation Fornax (the Furnace). The HUDF has long been an extremely fertile hunting ground for astronomers, as it contains at least 10,000 galaxies dating back to just 800 million years after the Big Bang, providing a glimpse into how the very first galaxies may have formed. When NASA's Hubble Space Telescope observed this pocket of the universe in late 2003, it clicked the first images of galaxies at the farthest distances ever known. At the time, Hubble's representatives said this record was "unlikely to be surpassed" until Webb comes onto the stage.

Two decades later, Webb observed the same region at similar depths that Hubble did, which means Webb could see galaxies as faint as its precursor in just one-tenth as much observing time. "The fact that we see hot, ionised gas is telling us exactly where stars are being born in these galaxies," Michael Maseda, an astronomy professor at the University of Wisconsin-Madison, said. "Now we can separate those areas from where stars already existed. That piece of information is very important because, billions of years later, we don't exactly know how galaxies became how they are today."



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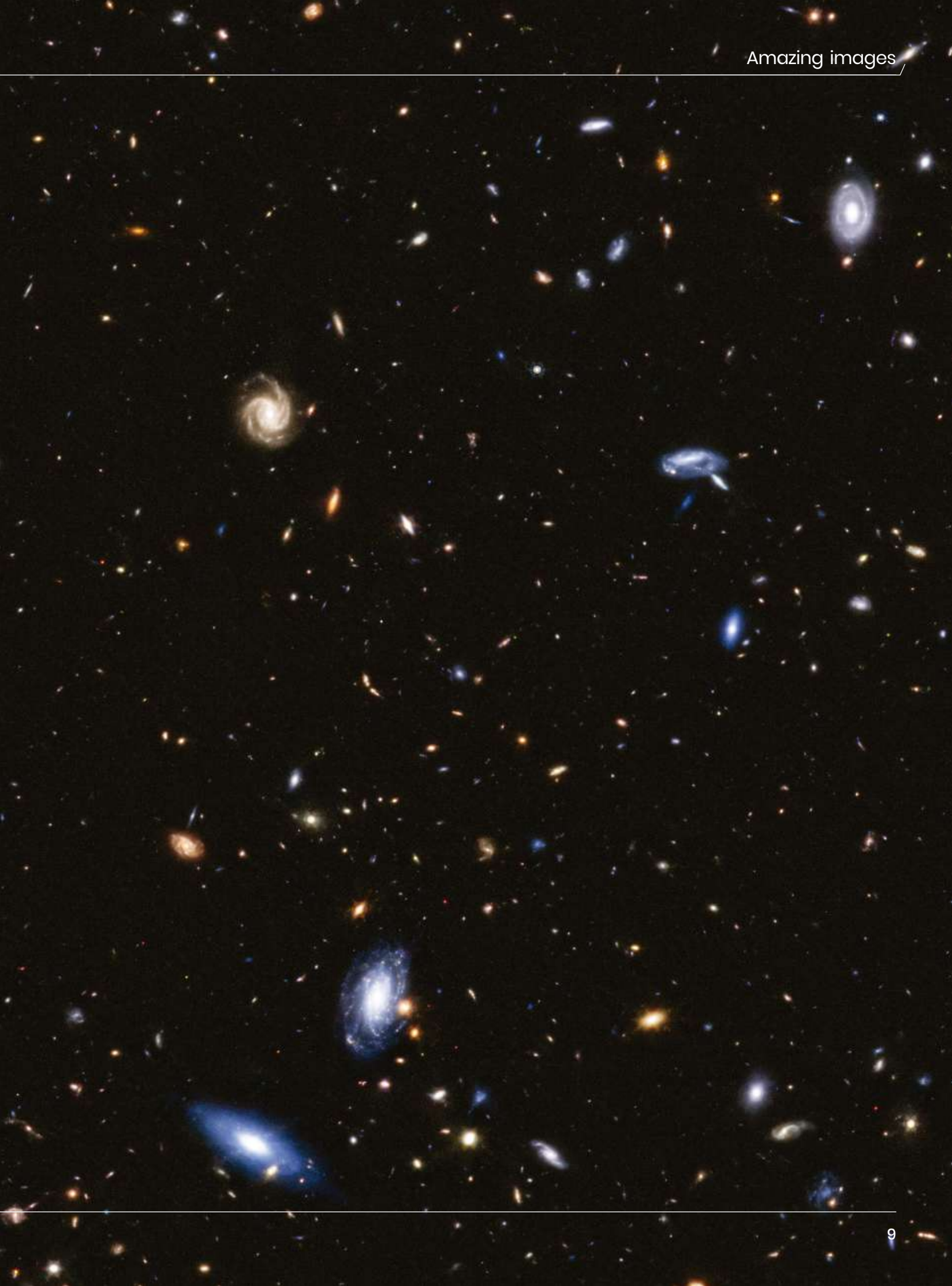


24 April 2023

Mars' mysterious moon Deimos

A moon of Mars showed off its pockmarked face in an unprecedented close-up view. Deimos, one of the small moons of Mars, was imaged by the Hope Mars mission from as close as 100 kilometres (60 miles) – the closest look yet. "These images and observations represent a significant step forward in our knowledge of Deimos, its atmosphere, composition, origins and what this means for our understanding of Mars more broadly," United Arab Emirates Space Agency officials said. For example, the spacecraft's observations of the composition of Deimos suggest the moon came from Mars itself, which is another step forward in resolving a long-standing debate about its origins. Previous studies suggested the moons' compositions could be similar to asteroids or dwarf planets, being made up of carbonaceous chondrites. Primitive meteorites are thought to be remnants of the original building blocks of planets. The moons are also potato-shaped and small, much like asteroids, suggesting Mars may have snatched them when they strayed too close to the Red Planet.

The new data from the Emirati mission was obtained from the Emirates Mars Infrared Spectrometer. It suggests that both Phobos and Mars are "more akin to a basaltic Mars than a D-type asteroid such as the Tagish Lake meteorite – often used as an analogue for the spectral properties of Phobos and Deimos," instrument scientist Christopher Edwards said.

© Emirates Mars Mission

Saturn reclaims 'moon king' title with 62 newfound satellites

Reported by Robert Lea

Astronomers have discovered 62 new moons orbiting the ringed planet Saturn.

The satellite haul brings the planet's total number of moons to over 100 and also means the gas giant takes back the crown as the Solar System's "moon king" from Jupiter.

Prior to this discovery, Saturn had 83 moons recognised by the International Astronomical Union, so the new batch brings the total number to 145. The discovery marks another milestone for Saturn, with the planet becoming the first world in the cosmos known to be orbited by more than 100 moons.

The new moons were discovered by a team led by Edward Ashton, a postdoctoral fellow at the Academia Sinica Institute of Astronomy and Astrophysics, who used a technique called "shift and stack" to find these smaller and fainter moons. The technique uses a set of images shifting at the same speed at which a moon moves through the sky to enhance the signal from that moon. Moons that are too faint to be seen in single images can reveal themselves in the resultant "stacked image." Astronomers have used this method to search for moons around Neptune and Uranus, but this is the first time it has been applied to Saturn.

The data was collected between 2019 and 2021 in three-hour spans by the Canada-France-Hawaii Telescope (CFHT) on top of Maunakea in Hawaii. It allowed the astronomers to detect moons around Saturn as small as 1.6 miles (2.5 kilometres) in diameter.

Though some of the moons had been spotted in 2019, it takes more than sighting an object close to a planet to confirm it is a moon and not an asteroid making a brief close passage to that planet. To change these objects from "suspected moons" to "confirmed moons" of Saturn, the astronomers had to track them for several years to ensure each is actually orbiting the gas giant.

Matching objects detected on different nights over the course of 24 months, the team tracked 63 objects that they ended up confirming as moons. One of these satellites was revealed back in 2021, with the remaining 62 moons gradually announced over the past few weeks. "Tracking these moons makes me recall playing the kids' game Dot-to-Dot, because we have to connect the various appearances of these moons in our data with a viable orbit," Ashton said. "But with about 100 different games on the same page, and you don't know which dot belongs to which puzzle."

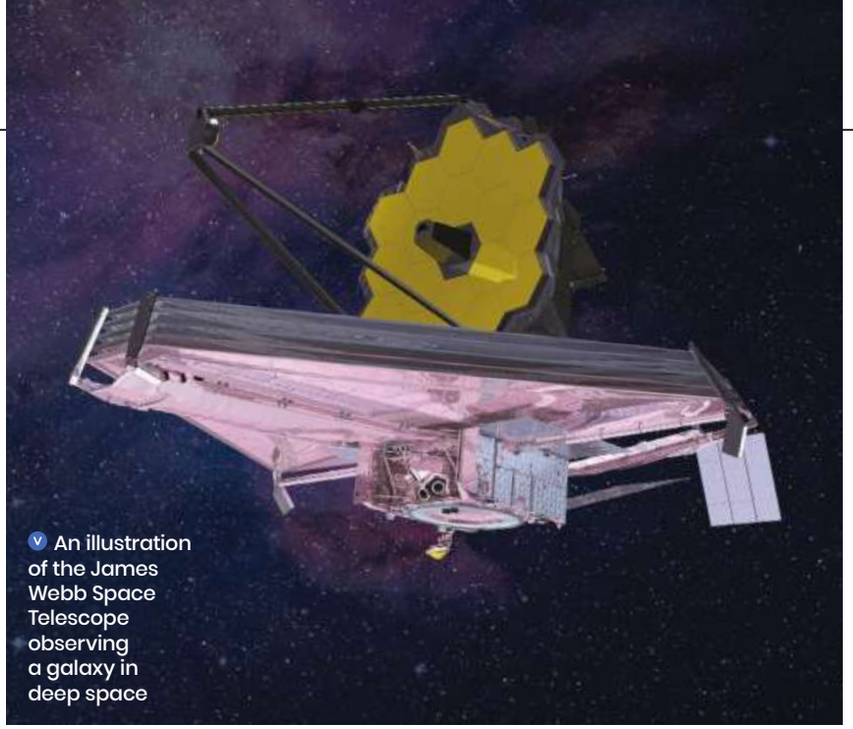
The newly discovered moons are irregular moons. This term refers to objects that are believed to have been captured by a planet's gravitational influence and end up orbiting it on large, flattened or "elliptical" paths that are more inclined in comparison to the orbits of regular moons.

Saturn now has 121 known irregular moons along with its 24 regular moons. Irregular moons tend to bunch up in groupings depending on the tilt of their orbits. Saturn's system currently hosts three of these groupings – the Inuit group, the Gallic group and the densely populated Norse group.

All of the newfound moons of Saturn fall into one of these three groupings. Three of the new moons belong to the Inuit group, but the majority fit in the Norse group.

"As one pushes to the limit of modern telescopes, we are finding increasing evidence that a moderate-sized moon orbiting backward around Saturn was blown apart something like 100 million years ago," team member and University of British Columbia astronomer Brett Gladman said.

An artist's impression of Saturn, looking toward the inner Solar System



An illustration of the James Webb Space Telescope observing a galaxy in deep space

James Webb Space Telescope catches ancient galaxy in the act of explosive star birth

Reported by Sascha Pare

Astronomers have used the James Webb Space Telescope (JWST) to stare through the dusty clouds of a distant star-forming galaxy to investigate its structure. They discovered the galaxy is in the midst of a starburst, an explosive surge in star formation possibly caused by a collision with another galaxy.

Located around 12 billion light years away, the galaxy GN20 is one of the earliest active star-forming galaxies studied in detail thus far by astronomers.

GN20 is located in a region of space called a galaxy overdensity or a protocluster. In these regions, galaxies will eventually group together to form a massive collection called a galactic cluster.

The early galaxy, which was seen as it was when the 13.8 billion-year-old universe was about 1.8 billion years old, is forming stars at a rate of around 1,860 times the mass of the Sun each year. Clumpy molecular gas surrounds the galaxy expanding out to a diameter of around 46,000 light years, and this star-forming matter is flattened into a giant rotating disk.

Star-forming galaxies are surrounded by dense clouds of dust and gas that collapse in over-dense patches to form stars; these also make them difficult to investigate. This is because these clouds are adept at absorbing visible light, but infrared light has an easier time slipping through. The JWST, which was designed to see the universe in infrared wavelengths, is ideal for investigating such galaxies.

To study GN20, astronomers led by Spanish Astrobiology Center scientist Luis Colina used observations made by the JWST's Mid-Infrared Instrument (MIRI) between 23 and 24 November 2022. They found that the early star-forming galaxy has a concentrated bright nucleus of densely clustered stars at its core surrounded by a diffuse envelope of gas. This inner structure of GN20 is birthing stars at a rate of about 500-times the mass of the Sun each year and has been doing so for around 100 million years. This nucleus is under 2,600 light years in diameter, while its gaseous envelope has a diameter of around 23,000 light years.

The centre of the gas is off-centre in relation to GN20's dense nucleus of stars, implying that GN20 has recently had an encounter with another galaxy. Interactions like this are often theorised to be the cause of intense periods of star formation. The research team concluded that GN20 will eventually become a massive galaxy resembling those found around the Milky Way, with its bout of intense star formation eventually coming to an end.

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Two 'super-Earth' exoplanets spotted in habitable zone of nearby star

Reported by Robert Lea

Astronomers have spotted two super-Earth exoplanets orbiting within the habitable zone of a nearby star. Each of the newfound worlds is slightly larger than our planet, with both circling the same red dwarf.

The exoplanets were spotted by NASA's Transiting Exoplanet Survey Satellite (TESS) as they crossed, or "transited", the face of their parent star, TOI-2095, which lies around 137 light years from our Solar System. This transit caused dips in the light from the star, and analysing those dips revealed the presence, as well as some characteristics, of the two planets.

As a red dwarf, TOI-2095 is part of the largest family of stars in the universe. Despite being cooler than the Sun, red dwarfs are known to experience violent outbursts of ultraviolet and X-ray radiation in their youth. This radiation could blow away the atmospheres of planets orbiting relatively nearby. As a result, scientists aren't sure if planets within a red dwarf's habitable zone – defined as the range of distances from a star in which liquid water could be stable on a world's surface – are actually hospitable to Earth-like life. This makes the two planets orbiting in the habitable zone of this red dwarf – which have been designated TOI-2095 b and TOI-2095 c, respectively – tantalising prospects for further investigation by astronomers.

The distance between the closest planet to the red dwarf, TOI-2095 b, and its star is around one-tenth of the average distance between the Earth and the Sun. The exoplanet, which is 1.39-times wider than our planet but has up to 4.1-times its mass, takes around 17.7 Earth days to orbit the star.

The system's second planet, TOI-2095 c, is a little farther out and takes 28.2 Earth days to orbit the red dwarf. This exoplanet has a diameter around 1.33-times that of Earth and has up to 7.5-times the mass of our planet. The planets likely have surface temperatures between 75 degrees Fahrenheit and 165 degrees Fahrenheit (24 to 74 degrees Celsius), researchers said.

Ambitious asteroid mission will tour seven space rocks

Reported by Andrew Jones

The United Arab Emirates (UAE) is targeting seven different space rocks with its mission to the main asteroid belt.

The mission was announced in 2021, but now a poster presented in June at the Asteroids, Comets, Meteors Conference in Arizona has revealed the specific targets for the mission. "The mission will launch in 2028 and visit seven main belt asteroids, including six high-speed flyby encounters en route to a rendezvous with the asteroid 269 Justitia," according to the document, which details the design of the mission. The targets include flybys of 10253 Westerwald, 623 Chimaera, 13294 Rockox, 88055, 23871, 59980 and a rendezvous of 269 Justitia.

After rendezvousing with 269 Justitia, the spacecraft will deploy a lander for an attempt to set down on the surface. Notably, only NASA's OSIRIS-REx and the Near-Earth Asteroid Rendezvous (NEAR) Shoemaker spacecraft and Japan's Hayabusa1 and Hayabusa2 probes have succeeded in soft-landing on an asteroid so far.

The target for the landing is another rarity. The roughly 33-mile-wide (53 kilometres) asteroid 269 Justitia has a reddish hue, possibly due to the presence of organic compounds called tholins, which are abundant on Pluto and other icy bodies in the outer Solar System.

The spacecraft will reach 269 Justitia in April 2034. If the asteroid formed in the outer Solar System, the UAE mission could provide unique insight into bodies out beyond Neptune.

The overall science objectives will investigate the origins and evolution of water-rich asteroids and assess their potential use for resources.

The spacecraft will use solar electric propulsion for its six-year-long voyage and will use gravity-assist flybys of Venus, Earth and Mars on its journey.

An illustration of two super-Earths orbiting the same parent star

An artist's illustration of the asteroid belt between Mars and Jupiter, the main destination of the United Arab Emirates' second interplanetary mission

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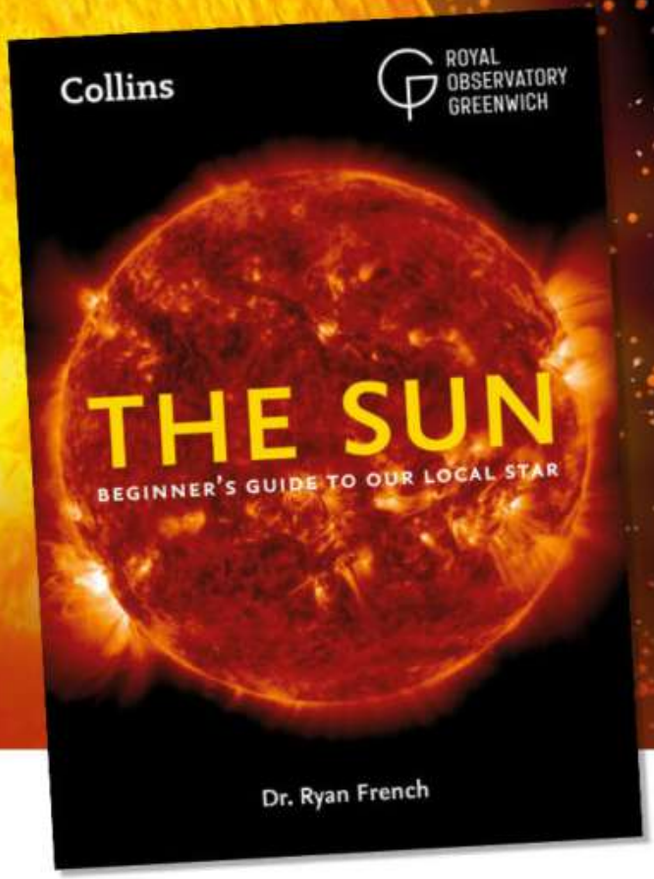

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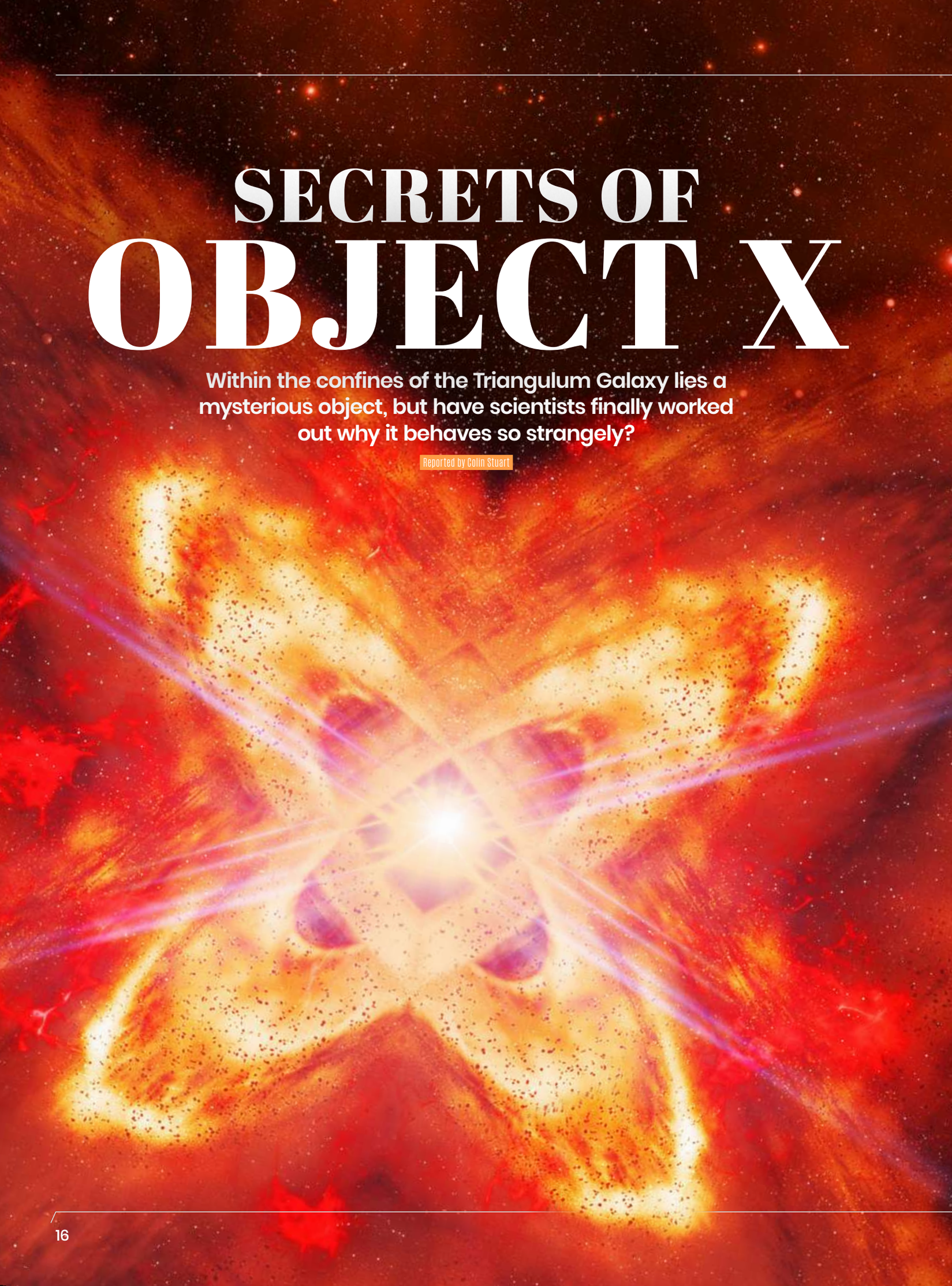
SECRETS OF OBJECT X

Within the confines of the Triangulum Galaxy lies a mysterious object, but have scientists finally worked out why it behaves so strangely?

Reported by Colin Stuart



Look up at the northern night sky, and you will be able to pick out the distinctive W-shaped constellation of Cassiopeia. If each of the two 'V's that make up this shape are seen as a downwards-pointing arrow then the right-hand one will guide you to a barely perceptible fuzzy smudge. This is the Andromeda galaxy, one of the furthest objects from Earth that is visible with the unaided eye. Yet there is one naked-eye object that's even further afield, although you will need incredibly dark skies to see it: the Triangulum galaxy (M33), named after the constellation that borders Andromeda.

It was when studying this distant city of stars over a decade ago that astronomers made a remarkable discovery – something that at first didn't make sense and that they are still scrabbling to fully understand. They've dubbed it Object X. "It has gained a certain level of notoriety," says Roberta Humphreys from the University of Minnesota, who has worked on deciphering the mysteries surrounding Object X.

Look at M33 in visible light – the same light that our eyes see in – and astronomers can barely make out Object X at all. Perhaps that's not surprising, given that the galaxy is some 3 million light-years from Earth. However, switching to mid infrared observations makes a big difference. Suddenly, Object X was the brightest thing in the entire galaxy, outshining tens of billions of stars.

The team that made the discovery, led by Rubab Khan from Ohio State University, started sleuthing. They looked back at old photographic plates of M33 taken in visible light from both 1949 and 1991. Object X wasn't there, so it hasn't been visible to ordinary telescopes knocking on the door for a century. Whatever the reason behind this, it is not short-lived – at least not on a human timescale.

So what is going on? Further observations offer some important clues. The meagre visible light it emits varies over timescales of weeks to months. The infrared light it kicks out varies a little, too. This is exactly how you would expect a star to behave, but if it is a star then why wasn't it showing up easily using ordinary telescopes?

The team suggests that Object X is a huge star tipping the scales at over 30 times the mass of the Sun. That would make it a supergiant star and possibly even a hypergiant. Such stellar goliaths are known to be incredibly unstable, particularly as they approach the end of their relatively short lives. They begin to spit out vast quantities of material into space. A single eruption can spew out as much mass as all the planets in the Solar System combined.

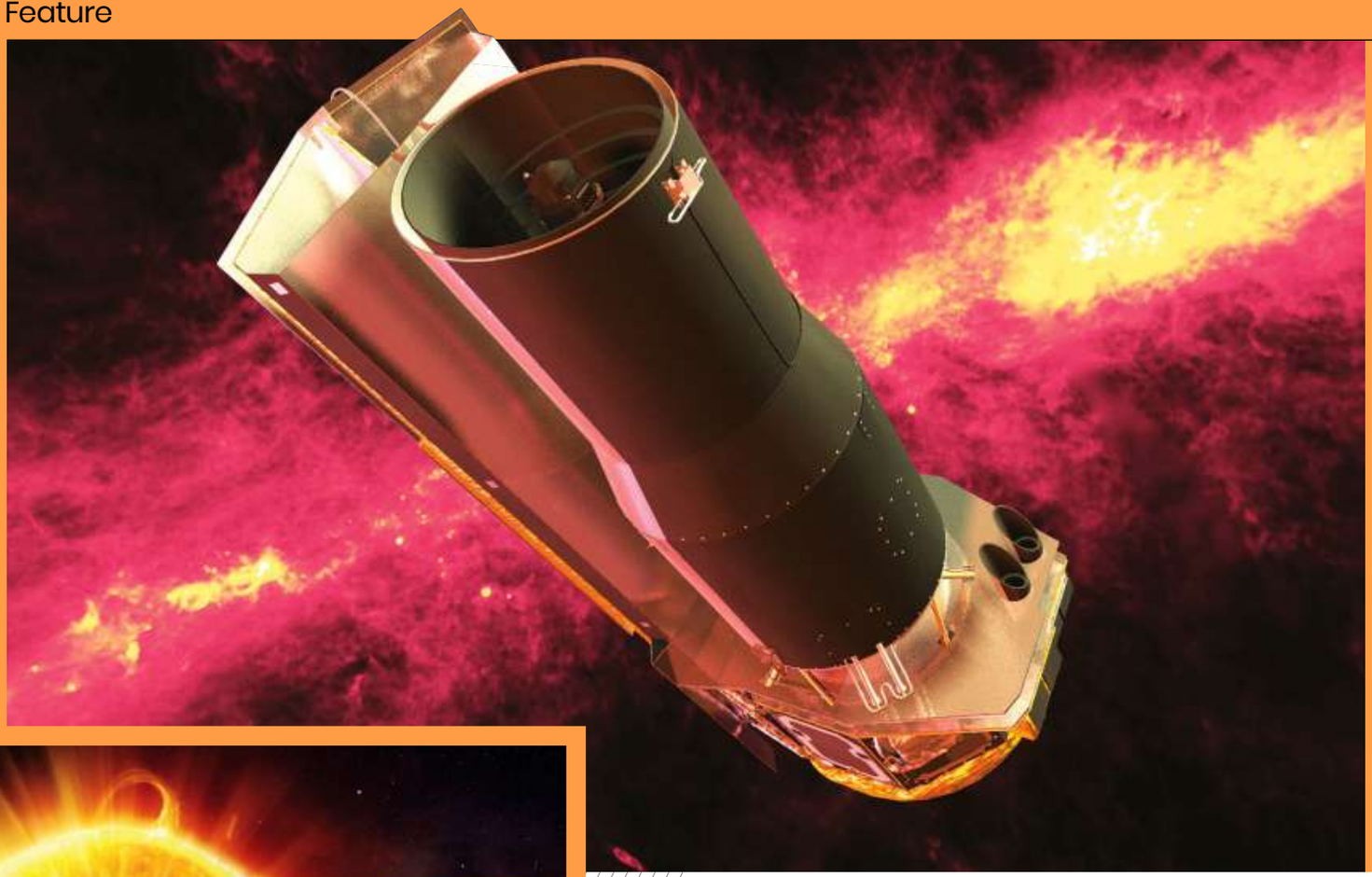
Something similar recently happened to the well-known star, Betelgeuse, in the constellation of Orion, The Hunter. It noticeably dropped in brightness, before reverting back again. Astronomers believe that it belched out gas totalling several times the mass of the Moon, which temporarily blocked our view.

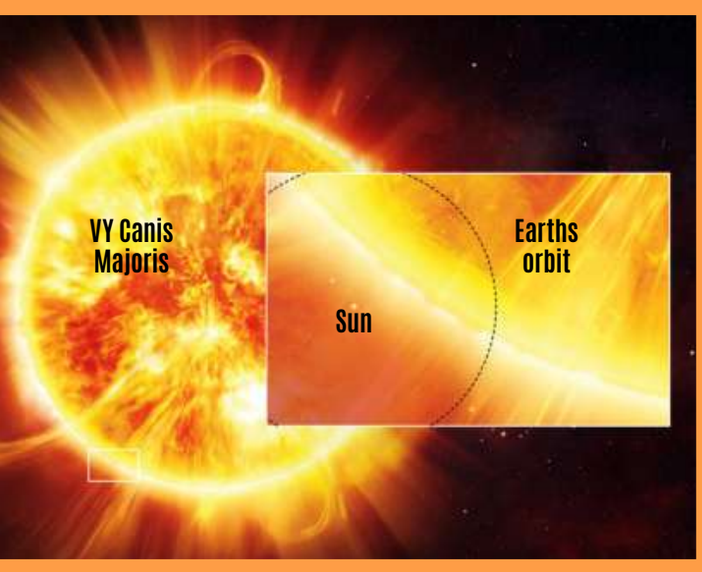
The ejected dust absorbs the star's visible light and then re-emits it in the infrared part of the spectrum. "It's like the Earth absorbing the radiation from the Sun during the daytime," says Humphreys. "If you lean against a brick wall in the early evening, it feels warm," she says. The wall is re-radiating the Sun's energy as infrared radiation. That would explain why Object X lit up like a Christmas Tree in infrared observatories like NASA's Spitzer Space Telescope.

"Object X reminds me of other stars," says Humphreys, citing one example in M33 called Variable A. Its story may offer some important clues about what to expect next for Object X. Back in 1950, Variable A was one the brightest stars in M33. It then dimmed dramatically, dropping in brightness by over 15 times. "It probably expanded and cooled –

The Pillars of Creation in visible and infrared, showing how the latter can peer through dust

© NASA, ESA/Hubble ; Getty





its surface temperature dropped from 6,000 degrees to 3,000 degrees," says Humphreys.

Yet infrared measurements made in the Eighties showed that a lot of the light emitted had shifted out of the visible part of the spectrum and into the infrared. "A episode of mass loss obscured the star by creating an envelope of circumstellar dust," Humphreys says.

But the effects of the dust were not permanent. While still obscured in visible light, in the mid-2000s, astronomers noticed its brightness in the infrared dropping. They concluded that the outburst event was waning and that the dust was being redistributed as the star recovered from the ordeal. Eventually, the clouds could clear, again revealing the star cocooned within. If the same process is unfolding around Object X then the outburst must predate the photographic plates taken in 1949. Perhaps one day it will shine in visible light again.

Huge stars like Object X and Variable A are rare. Add in the fact that they are often enshrouded in dust and they are hard to study. Astronomers know of just ten examples in our own galaxy, the Milky Way. Their view of those is often hampered even further by the dust and gas in the galactic disc. "Most observations are restricted to a small area around the Sun," Humphreys says. So when astronomers do get a chance to observe hypergiants, they grab the opportunity with both hands.

One of the most studied examples is a star called Rho Cassiopeiae. Just 3,400 light-years away, it is almost 900 times closer to us than Object X in M33. You'll find it in the same W-shaped constellation that points the way towards the Andromeda and Triangulum galaxies and its vital statistics are dizzying. For starters, it is 300,000 times brighter than the Sun. It is also 500 times wider, meaning you could fill it up with 125 million Suns. That's so wide that its outer edge sits at double Earth's distance from the Sun, although even that is smaller than the very biggest stars, such as VY Canis Majoris and UY Scuti, both of which could fit billions of Suns inside.

Normally, Rho Cassiopeiae shines with an apparent magnitude of 4.5. Apparent

Object X is the brightest infrared source in Spitzer observations of the M33 galaxy

One of the biggest stars in the universe compared to the Sun and Earth's orbit

M33, otherwise known as the Triangulum Galaxy. It's home to Object X

magnitude is a measure of how bright an object appears in our night sky; the higher the number, the dimmer the object. Anything beyond about magnitude 6 is not visible without binoculars or a telescope. Rho Cassiopeiae has undergone several dimming events in 2001, 1946 and 1893, which saw its apparent magnitude drop to around 6. Again, this is because of extreme mass loss events, which temporarily obscured our view.

For the best example of just what these huge stars can do, astronomers look to the colossus Eta Carinae in the constellation of Carina, The Keel. It sits 7500 light-years away and tips the scales at between 150 and 250 times the mass of the Sun. It was a 4th magnitude star, but for a brief period in March 1843 it suddenly became the second brightest star in the night sky. It then faded beyond the limits of human eyesight.

Even today, astronomers can see the after effects. Eta Carinae is surrounded by a cloud of gas and dust known as the Homunculus Nebula. Its material continues to rush outwards at up to 1.5 million miles per hour, concentrated into two lobe-shaped regions around Eta Carinae's poles. It forms knots, jets, arcs and lumps that can contain 3,000 Earths worth of material. In total, the Homunculus Nebula stretches to some 0.6 light-years across. That's almost 6 trillion kilometres wide or nearly 40,000 times the distance between Earth and the Sun.

Like Object X, this material absorbs the visible light from the star and re-radiates it in the infrared. By making infrared observations, astronomers can estimate the total amount of dust in the nebula. The answer they get is about half a Sun's worth. Using a typical dust to gas ratio, that means

LARGE BINOCULAR TELESCOPE (LBT)

1 First observation
The first image from the LBT was NGC 891, an edge-on spiral galaxy in the NGC 1023 group that is located in the Canes Venatici cloud of the VS.

2 Star formation
The LBT's observations of the Trapezium region have revealed the positions of young stars in their orbits and confirmed a theory about star formation.

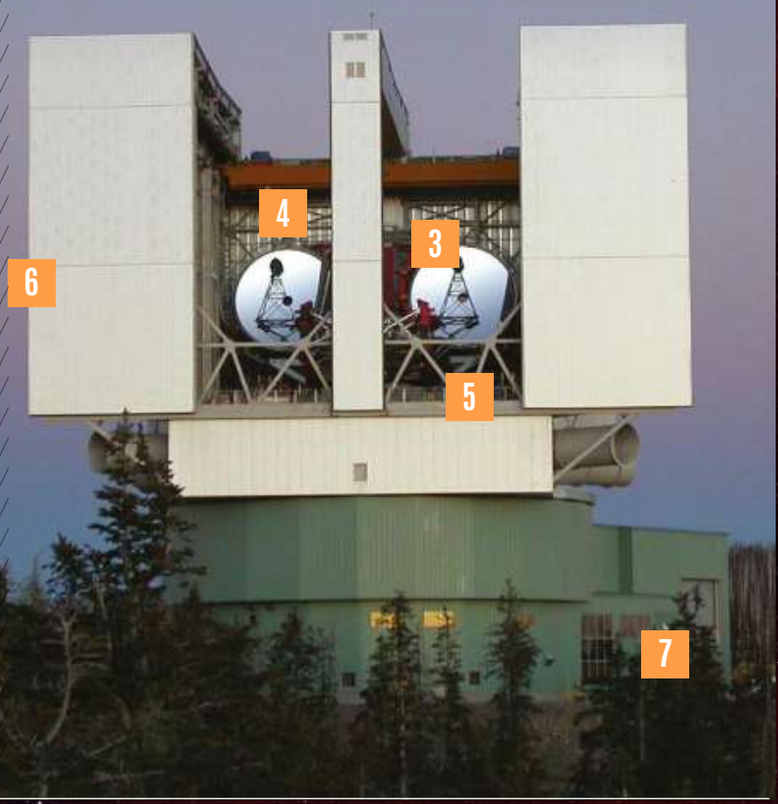
3 Mirrors
The LBT has two 8.4-metre- (27.6-foot-) wide mirrors that are separated in the centre by 14.4 metres (47.2 feet) and an adaptive mirror to correct distortion.

4 Prime focus camera
Looking at Messier 81 in the M81 Group using the UV-blue camera revealed the faint dwarf galaxy, Holmberg IX.

5 Installation
The LBT saw first light with a single mirror in October 2005, and the second mirror was installed in 2006.

6 Partners
The LBT is a joint project of several universities and scientific organisations located in the US, Italy and Germany.

7 Location
This telescope is located at Mount Graham International Observatory, in the Pinaleño Mountains of Arizona, USA.



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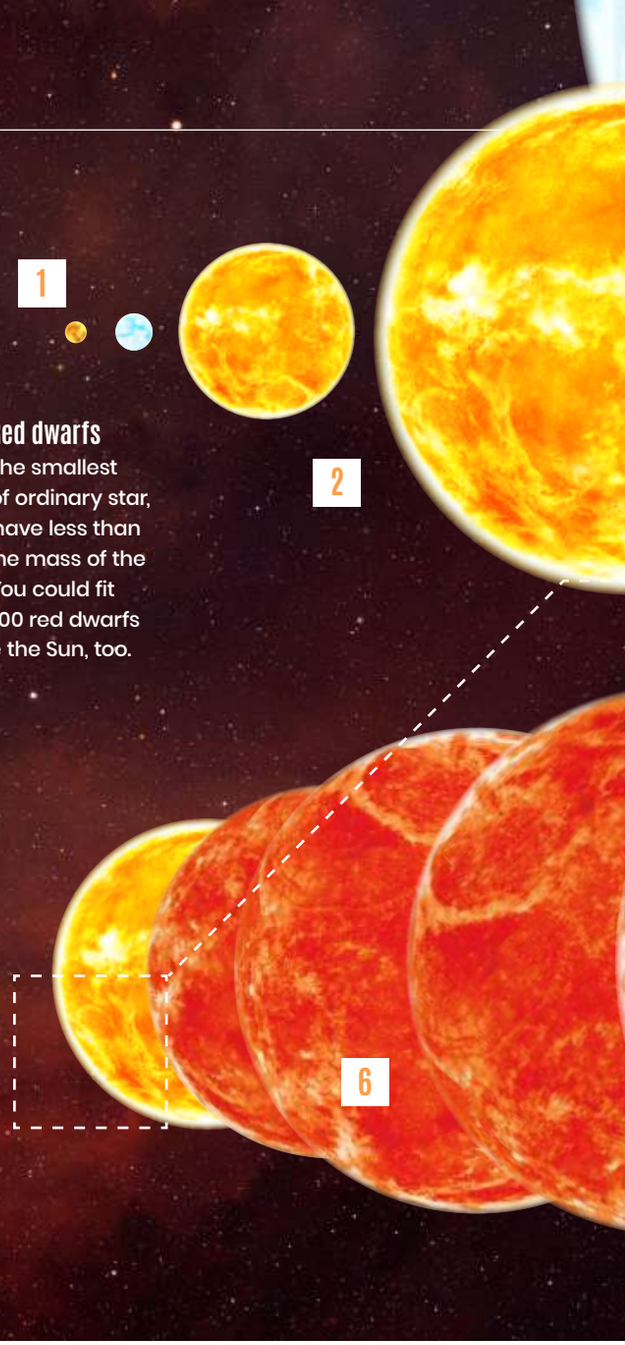
THE SIZE OF STARS



1 Neutron stars
The remnants of the deaths of massive stars, neutron stars are typically the size of a city. Yet they still contain so much stellar material that they weigh more than Mount Everest.

2 White dwarfs
About the size of Earth, these objects are what's left behind after the deaths of Sun-like stars. Our Sun will become a white dwarf in about 6 billion years' time.

3 Sun-like stars
Our Sun sits in the middle of the range of different star sizes, but it is not an "average sized star". It is still bigger than most stars in the universe as 75 per cent of all stars are red dwarfs.

4 Red dwarfs
The smallest kind of ordinary star, they have less than half the mass of the Sun. You could fit over 100 red dwarfs inside the Sun, too.

5 Red giants
When stars like the Sun begin to die, they swell into red giants, consuming their inner planets in the process. After the Sun enters this phase, its outer edge will reach Earth's current location.

6 Supergiants
These monsters can be 1,000 times wider than the Sun and a million times as bright. Some are still in the main part of their lives, but red supergiants are on their way to exploding as a supernova.

7 Hypergiants
The biggest of the lot - so big you could fit over a billion Suns inside, or more than a million billion Earths. They have at least 25 times the mass of the Sun and will likely end their lives as black holes.

the nebula also contains 20-30 solar masses of gas. In other words, Eta Carinae has shed 20-30 Suns' worth of material and yet still shines on regardless.

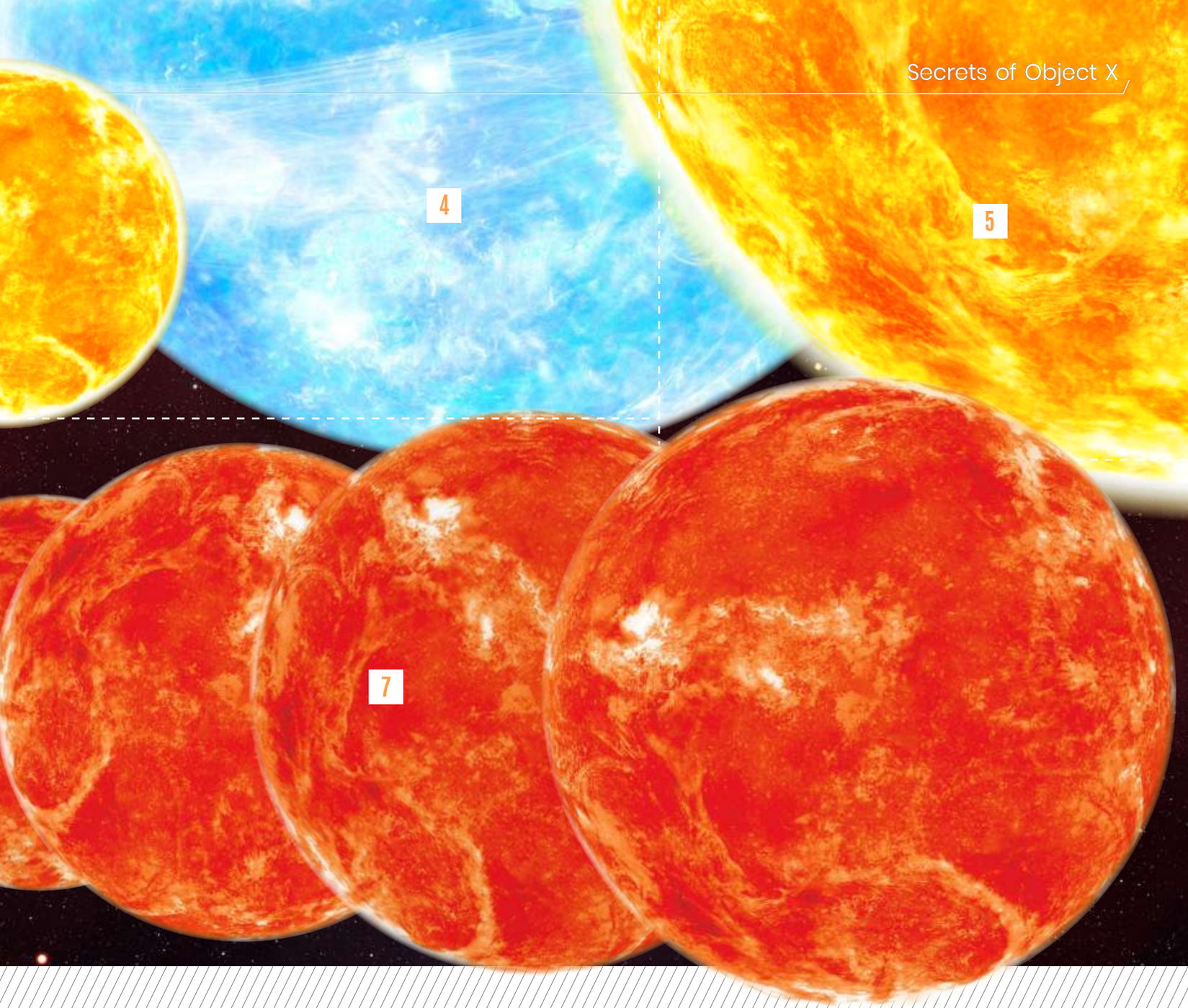
What could be causing these massive stars to be losing so much of themselves to space? Humphreys thinks it is down to the star's magnetic field, which loops from pole to pole. That could explain the distinctive lobes of the Homunculus Nebula. Our own Sun's magnetic field is constantly changing. It is responsible for a vast array of effects, including sunspots, solar flares and the solar wind, although the most spectacular magnetic event that unfolds on the Sun is called a Coronal Mass Ejection (CME). During these episodes, the Sun can spit out a mountain's worth of material in one go.

According to Humphreys, these events are amplified on supergiants and hypergiants. "It's scaled up by a factor of a billion or even a trillion," she says. The star's magnetic field is up to five times stronger than on the Sun and the energy stored within it is a thousand times greater. That leads to much more violent outbursts. A single eruption can weigh more than Jupiter, the Solar System's largest planet.

Obscuring light isn't the only mechanism that could see a star that loses mass suddenly disappear from view. Massive stars usually detonate as searingly bright supernovae explosions when they die, leaving behind a black hole. However, some researchers suspect that it may be possible for the most massive stars to collapse directly into a black hole if they lose mass. "They go out with a burp instead of an explosion," says Humphreys.

Astronomers surveying the sky with the Large Binocular Telescope did report a couple of potential candidates for this process. However, Humphreys isn't completely

The intense and crowded environment around one of the most famous hypergiant stars



FURTHEST OBJECTS VISIBLE TO UNAIDED EYE

Nu Cephei

Seen in the constellation of Cepheus, this supergiant star is 100,000 times brighter than the Sun. That's why you can see it despite it being almost 5,000 light-years from Earth. It's arguably the furthest star visible without binoculars or a telescope.

Messier 13 (M13)

This is a globular cluster – the name given to a dense group of very old stars. It is just about visible without binoculars in dark skies within the constellation of Hercules. It sits over 20,000 light-years away.

The Magellanic Clouds

Most readily visible from the Southern Hemisphere, the Large and Small Magellanic Clouds are two of the satellites of our Milky Way galaxy. Unmissable with the unaided eye, they are located 180,000 and 210,000 light-years away respectively.

Andromeda (M31)

Often billed as the most distant thing that is visible with eyes alone, it's the nearest major galaxy to the Milky Way. At 2.5 million light-years away, the light that we see today has been travelling across space since humans first made tools out of stone all those years ago.

Triangulum (M33)

While Andromeda can be seen from a moderately dark sky, you need impeccable darkness to see Triangulum – officially noted by the Guinness Book of Records as the most distant object that is visible to the unaided eye. It's 3 million light-years from Earth.

© NASA, ESA/Hubble

convinced. "When I looked at the stars more closely, I thought they were just as likely to be examples of stars like Variable A."

Part of the problem is our limited ability to study stars like Object X in detail. Our atmosphere blocks infrared radiation from reaching the ground, so you need to get high above it to make your observations. We did have NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA), a Boeing 747SP aircraft modified to carry a 2.7-metre reflecting telescope. Flying in the stratosphere put it above 99 per cent of the atmosphere. However, it was discontinued in 2022 due to the high costs associated with the flights.

The much-lauded James Webb Space Telescope is an infrared observatory, but it is designed to look at faint objects in the very distant universe. "These stars are too bright for JWST," says Humphreys. "They would saturate the instrument."

So for now, the focus will remain on large-scale infrared surveys of the night sky, looking for anything that stands out like Object X. Humphreys thinks that this is important work. "It's these special stars that are doing interesting things that may be the clues to understanding more normal stars, because those stars may one day do those unusual things, too."

Colin Stuart
Space science writer
Astronomer and space science writer Colin holds a degree in astrophysics, has written over 17 books on space and has an asteroid named in his honour: 15347 Colinstuart.

TYPES OF RADIATION

Your guide to the different wavelengths of these rays

Radio waves
Rapidly rotating neutron stars called pulsars emit pulses of radiation that astronomers pick up as repeating bursts of radio waves.

Microwaves
The leftover radiation from the Big Bang - known as the Cosmic Microwave Background - is in this part of the electromagnetic spectrum.

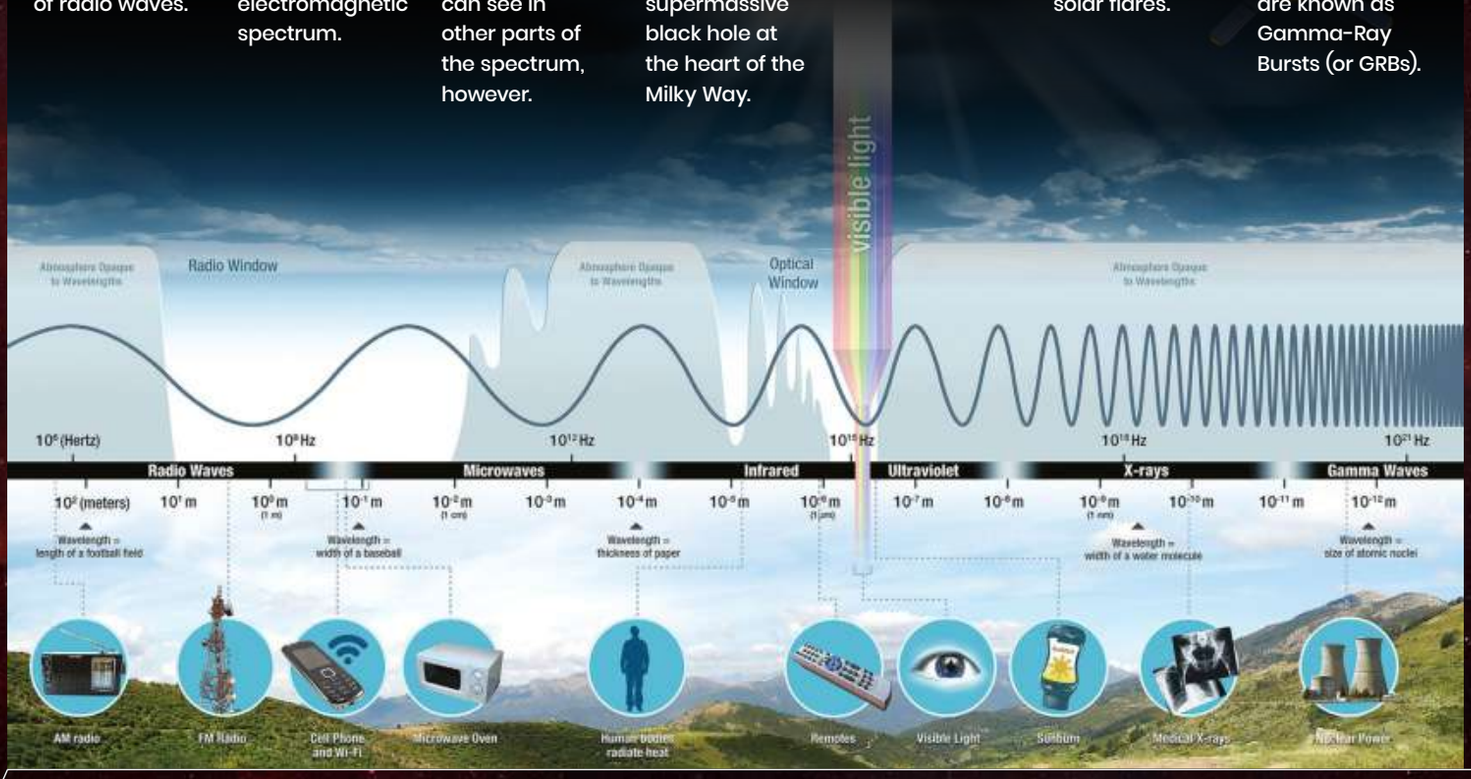
Visible light
The Sun's radiation peaks in visible light, which is why our eyes have evolved to be sensitive to it. Some animals can see in other parts of the spectrum, however.

Infrared
Astronomers use infrared observations to peer through dust - such as looking through the galactic plane to the supermassive black hole at the heart of the Milky Way.

Ultraviolet
Jupiter's aurorae are only visible in ultraviolet light. It is also produced by the hottest, largest and youngest stars.

X-rays
Material swirling into a black hole becomes very hot and often produces intense X-ray radiation. X-rays also come from solar flares.

Gamma-rays
The most energetic form of light, it is often created by cataclysmic events such as colliding stars. These events are known as Gamma-Ray Bursts (or GRBs).



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FOCUS ON

PENTAGON HAS "NO CREDIBLE EVIDENCE" OF ALIENS OR UFOS

The new UFO office has no proof of any extraterrestrial or extraordinary objects

Reported by Brett Tingley

The director of the Pentagon's new UFO office shot down hopes that the buzz over unidentified anomalous phenomena (UAP) supports claims of extraterrestrial visitation. Sean M Kirkpatrick, the first director of the Pentagon's new All-Domain Anomaly Resolution Office (AARO), testified before the United States Senate Committee on Armed Services on 19 April. The hearing had two portions, one closed to the public and one open.

During the open portion, Kirkpatrick stated that out of the hundreds of UAP cases his office has reviewed, "AARO has found no credible evidence thus far of extraterrestrial activity, off-world technology or objects that defy the known laws of physics." The AARO director acknowledged that this conclusion might be "unsatisfying" to those who believe they have witnessed incontrovertible evidence of physics-defying craft.

As Kirkpatrick stressed, UAP cases often "resolve into readily explainable sources" when there is scientific data at hand. "The majority of unidentified objects reported to AARO demonstrate mundane characteristics of balloons, [uncrewed] aerial systems, clutter, natural phenomena or other readily explainable sources."

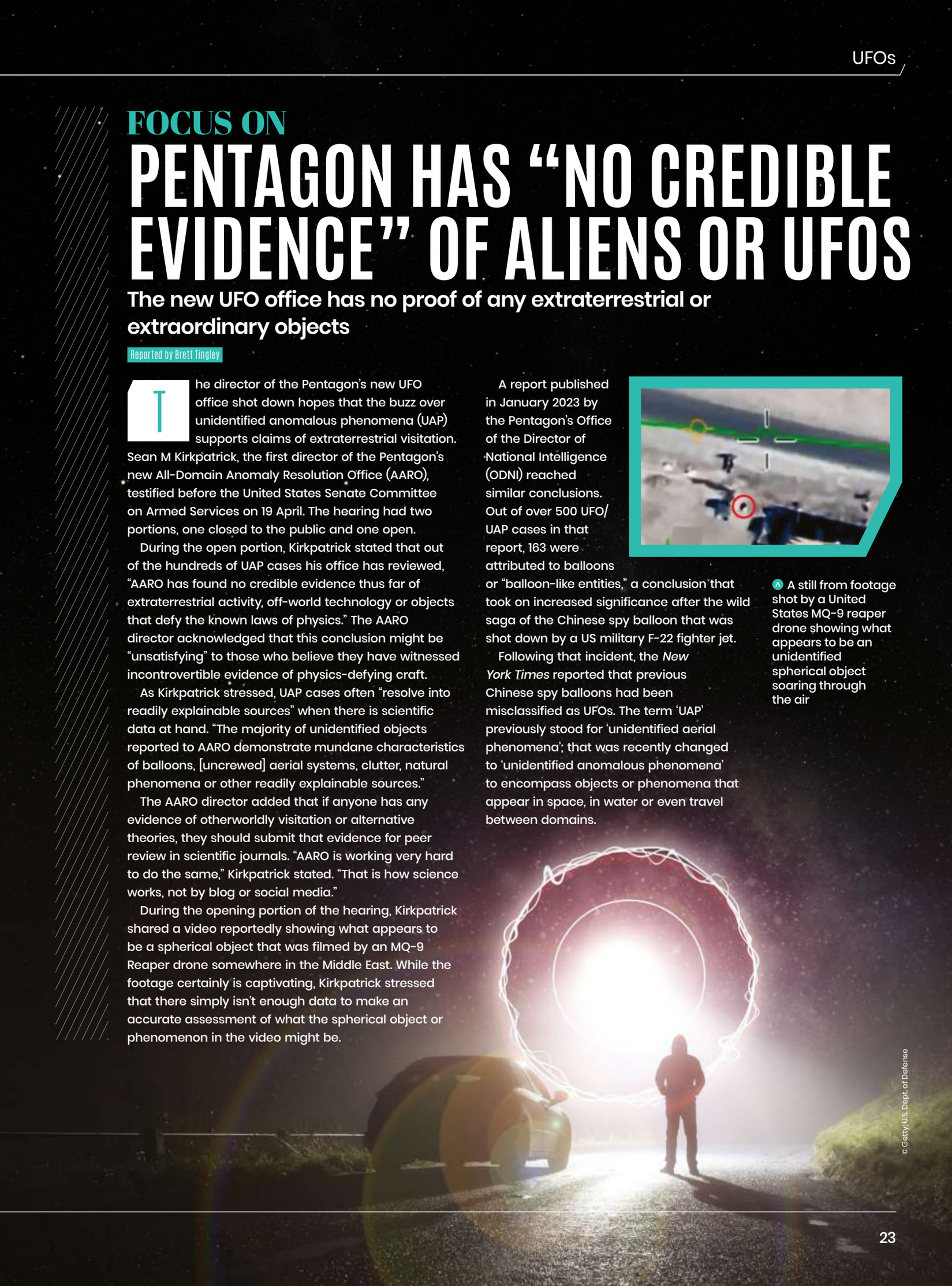
The AARO director added that if anyone has any evidence of otherworldly visitation or alternative theories, they should submit that evidence for peer review in scientific journals. "AARO is working very hard to do the same," Kirkpatrick stated. "That is how science works, not by blog or social media."

During the opening portion of the hearing, Kirkpatrick shared a video reportedly showing what appears to be a spherical object that was filmed by an MQ-9 Reaper drone somewhere in the Middle East. While the footage certainly is captivating, Kirkpatrick stressed that there simply isn't enough data to make an accurate assessment of what the spherical object or phenomenon in the video might be.

A report published in January 2023 by the Pentagon's Office of the Director of National Intelligence (ODNI) reached similar conclusions. Out of over 500 UFO/UAP cases in that report, 163 were attributed to balloons or "balloon-like entities," a conclusion that took on increased significance after the wild saga of the Chinese spy balloon that was shot down by a US military F-22 fighter jet.

Following that incident, the *New York Times* reported that previous Chinese spy balloons had been misclassified as UFOs. The term 'UAP' previously stood for 'unidentified aerial phenomena'; that was recently changed to 'unidentified anomalous phenomena' to encompass objects or phenomena that appear in space, in water or even travel between domains.

A still from footage shot by a United States MQ-9 reaper drone showing what appears to be an unidentified spherical object soaring through the air



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PLUTO ORBITER AND LANDER

US aerospace consultancy Princeton Satellite Systems is working with NASA on an engine that could open up the Solar System

1 Lander
Pluto's surface proved far more active than we expected, and the DFD would provide the capability to carry a surface lander to Pluto.

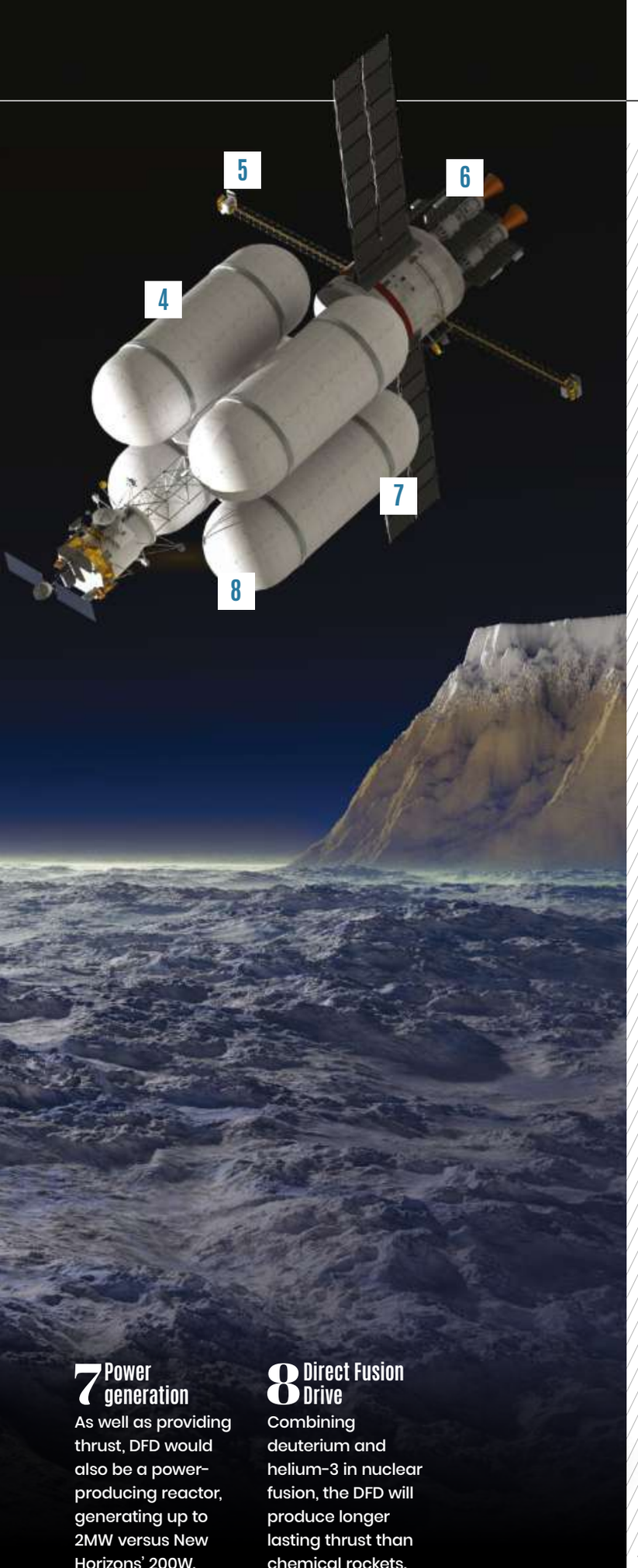
2 Pluto
39-times further from the Sun than Earth, our understanding of Pluto was revolutionised by the New Horizons flyby in 2015.

3 Timeline
Princeton hope to have a demonstration reactor running in the 2020s and the first DFD-powered robots in space in the 2030s.

4 Orbiter
New Horizons was a flyby mission, but the Princeton Pluto mission could place a satellite into Plutonian orbit for long-term observation.

5 High gain communication
Having more power makes it possible to transmit more data quicker, though it will still take signals around five hours to reach Earth.

6 Magnetic nozzles
The temperature of the exhaust will be so great that it will have to be directed by magnetic fields, as no material could withstand it.



7 Power generation
As well as providing thrust, DFD would also be a power-producing reactor, generating up to 2MW versus New Horizons' 200W.

8 Direct Fusion Drive
Combining deuterium and helium-3 in nuclear fusion, the DFD will produce longer lasting thrust than chemical rockets.

We are used to the idea of hopping between planets or even star systems in fiction, but the real distances, even within our own Solar System, are difficult to comprehend. If we are to truly explore and settle in space we need a new form of propulsion, and a New Jersey-based company, Princeton Satellite Systems, has just received a NASA contract to work on the design of one: the Direct Fusion Drive (DFD). New Horizons was one of the fastest spacecraft ever launched, yet it took over nine years to reach Pluto. It pushed the limits of our capability and delivered its extraordinary data from a 400-kilogram (880-pound) craft with just 200 watts of power – that's lighter than a grand piano and using less energy than a couple of light bulbs. This is because there is only so much energy available in chemical fuels, so space missions typically have a short sharp rocket burn at the start and then months or years of coasting as they have to go the slowest and most efficient route.

But the DFD would work on a nuclear reaction called fusion. This is not like nuclear fission, which is used in current power stations and occurs where energy is released by splitting heavy atoms like uranium. In fusion, energy is released by combining light atoms, and in DFD's case those light atoms would be deuterium and helium-3; this method is how stars shine and produces much more energy without creating any nuclear waste, but it is difficult.

Princeton's engine is based on an innovative concept from the Princeton Plasma Physics Laboratory called the Field Reversed Configuration (FRC). In this reactor the fusion fuel is trapped in a cylinder of magnets and heated up to millions of degrees Celsius by radio waves beamed into the chamber, similar to a microwave oven. The challenge for all fusion projects is in containing plasma at these tremendous temperatures, so the FRC reactor uses a special arrangement of rotating magnetic fields to create a self-contained rolling 'smoke ring' of plasma in the chamber.

Used in space as the basis for the DFD, the gases undergoing fusion would heat up extra gas passed through the reactor. Then the whole lot would be allowed to escape out of a nozzle formed of magnetic fields to produce thrust. Rocket thrust strongly depends on how hot the working fluid gets and how fast it escapes the nozzle. As fusion engines get much hotter than conventional rockets, it could produce more thrust from less fuel and for much longer.

Princeton's NASA project will develop enhanced models of how DFD would work, and apply this data to the design of a fusion-enabled Pluto mission. Initial studies suggest a 1,000-kilogram (2,204-pound) craft, featuring an orbiting satellite and a surface lander, could be delivered to Pluto in just four years. Another benefit of the DFD is that it could function as a power-generating reactor even when it is not producing thrust; the prospective Princeton Pluto mission could have 2 million watts of power at its disposal. With this project, NASA is laying the foundations of a transformation in propulsion.

BIO

Ben Miller

Known in the UK as being one-half of the comedy duo Armstrong and Miller, Ben Miller has appeared in a number of films and TV series. He abandoned a PhD in physics in favour of comedy but his love of science and astronomy remains strong. Having presented an episode of the BBC science series *Horizon* and written *It's Not Rocket Science*, Miller now seeks to chart and explain humankind's search for alien life.

Ben Miller

"Technology has really won the argument"

Comedian, actor and lover of all things science, Ben Miller has documented the search for alien life in a new book with optimism for the future. Are we really alone in the universe?

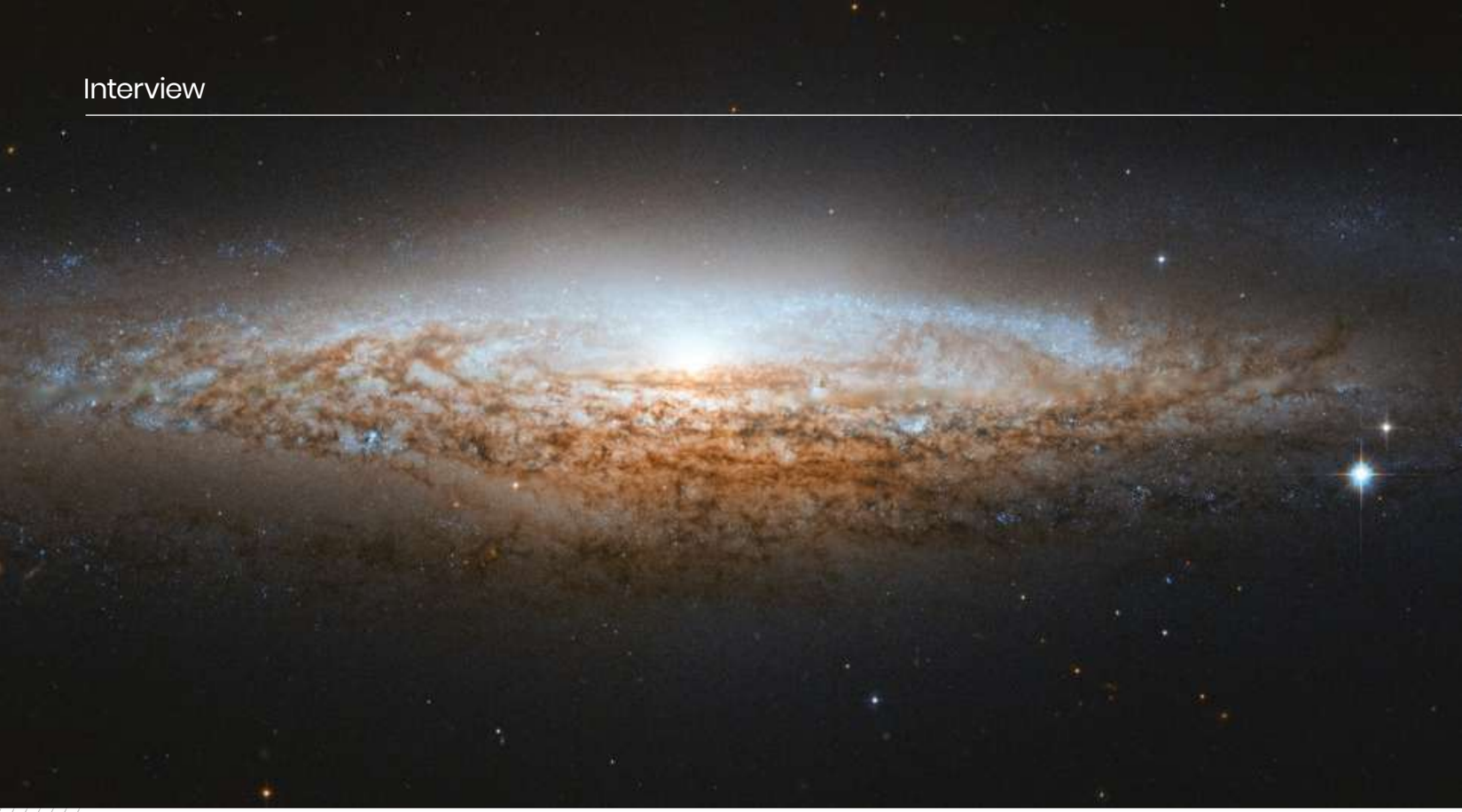
Interviewed by David Crookes

Although you've just written a book about alien life, you've got three young children. Has that made you reassess life in general?
I think a new baby makes you reassess a lot of things in your life, from home furnishings right on up to the existence of God. But the reason for writing the book – which was started three or four years ago – was to continue from where I left off with my first book, *It's Not Rocket Science*.

I found that I was fascinated by biology and the extraordinary advances being made in that area, and I also kept stumbling across different areas where people were talking about alien life and I just thought it would be a great thing to bring all of those things together in one book and talk about the real science of aliens. So my route into *The Aliens Are Coming!* was sort of through that. It's why this book starts where the last one leaves off, because I ended the first with a discussion of extraterrestrial life.

You say in your book that, as a boy in the 1970s, the hopes of finding life kept diminishing the more space was being explored. Was that disappointing for you?
It was a really depressing time. It was beautifully summed up by [late astronomer] Carl Sagan in his book, *Pale Blue Dot: A Vision Of The Human Future In Space*, in 1994: "The Earth is the only world known, so far, to harbour life. There is nowhere else, at least in the near future, to which our species could migrate." The 1970s was a golden age for robotic missions and that was an extraordinary period: we sent stuff to Venus and all the way out of the Solar System. Amazing. But then things just slid. We're actually now entering a golden age for telescopes and I think it's amazing what our telescopes can do now; just incredible.

V The past few decades have seen countless space missions and crucial advances in our understanding of space and space travel



Some people claim to have seen UFOs but the nearest thing officially seen is this UFO-shaped galaxy taken via the Hubble Space Telescope

You had started a PhD in physics but you abandoned it in favour of a career in comedy. Do you ever regret that decision?
No, no, oh my God, no. It's the best decision I ever made. I'd have made a terrible scientist. I would not have had the patience or the acumen, no, absolutely not. But it's only through being on the sidelines that my admiration for people who do it as a job has deepened. We all know scientists are incredibly gifted and really work in public service. It's not for financial reward or status or anything else. They are working at it and finding amazing stuff.

I mean, NASA, isn't that the coolest organisation ever? If NASA didn't exist, you would have to make it up. It's amazing and real and not like Spectre or anything. Some of the most intelligent people get together in a special organisation with a really cool logo to investigate space! That's brilliant.

Mars Express orbiter aims to find liquid water on the Red Planet, which could be trapped underground, maintained by temperature and pressure

© NASA; Seth Shostak

Are people surprised when you tell them about your interest in science?
They are, to be honest, but I think that's fine. You wouldn't think Rod Stewart was into train modelling, would you? If things are a hobby, then I think it's okay that it's unexpected, because a hobby is usually something completely different to what you do for a living anyway. Certainly, in a world of make-up, wigs, sequins and garments, to occasionally cover a scientific paper is pretty cool.

Have the discoveries made in relation to our Solar System and the speculation of a Planet 9, together with the work done by the ESA with comets, been bringing your childhood sense of wonder back to you?
Yes, I just find it all amazing, and anything to do with the Solar System is incredible. The Planet 9 stuff is extraordinary and the fact we can still be discovering such huge things about our Solar System just shows that we don't know the beginnings of it all really.

You make an interesting point at the start of your book where you discuss sending messages out into space – the likelihood of these messages being picked up is pretty low because of all the various circumstances that need to be in place for it to happen. Why do you think scientists have made the sending of messages into space one of the methods of searching for aliens?
I think we just have to do whatever experiments are available to us at the time. I don't think anybody would pretend that [sending messages out into space] is the most efficient way of finding extraterrestrial life but that's all that's been available, isn't it? It's extraordinary that, here on Earth, radio waves are quite an old technology and not a technology that we're expected to use much longer for interstellar communications.

Lasers are taking over from radio waves and, who knows, in the future gravitational waves may take over after that. So it's kind of about what's available to us, and the belief that we can look and should look for extraterrestrial life. Even with the most optimistic estimates for the number of intelligent civilisations out there, we are still going to have to search one million or 10 million Sun-like Solar Systems before we find a civilisation that we can signal to. There will be others out there but the timing won't be right.

Do you think we're looking in the right place and considering all the right circumstances? Here on Earth we are seeing life in the most unexpected of locations, aren't we?
Exactly. Of course, now we know there is running water on Mars, that makes all the difference as well. We've looked in very dry places, so to look in places where there is water is amazing. We still have the Martian meteorite – the Allan Hills 84001 meteorite – which, to this armchair biologist, looks like it has living things in it, but obviously they are very small. However, they still look like living things to me.

Do you believe alien life is out there and that we will come into contact with it at some point?
I do. I don't know if we will come into contact. It's my belief that bacterial life will be widespread and common, and within a decade we might detect that with our telescopes, not directly, but indirectly by analysing the atmospheres of nearby planets. That's probably the next bit of information we are going to have. There's the possibility of finding some kind of bacterial life on Enceladus or Europa, but you are looking at several years from now.

Beyond that, however, there's a chance of finding bacterial life on Mars. I can imagine the chances are pretty good of finding bacterial life elsewhere in the Solar System, and hopefully finding a living atmosphere, if you like, where the gasses in the atmosphere are not in chemical balance and show that there is some organism keeping the ball in the air. In terms of actually managing to pick up a signal, that's so unlikely. Civilisations might last for thousands of years and overlap but technologies don't and that's the problem.

Your book makes the clear distinction between the scientific search for alien life and the people who will talk about their accounts of UFOs...
I've heard all kinds of stories. There are those which say the American intelligence service know of the existence of aliens, and that presidents are hiding it and if you're high in government or the military then you're privy to information that aliens are here, now, on this planet. That's a universal thing. You find it in the UFO world and in Scientology and it seems to be a persistent myth. There is obviously some very deep primal feeling. Some of the more bizarre alien abduction stories are quite fun, those who are abducted and probed – you hardly need to make the case how that speaks to some deep primal, psychological trait of humanity.

This alien-looking creature from Earth is seen as the best candidate for being able to live on another planet. A tardigrade can survive absolute zero temperatures, the boiling point of water and radiation. It is an extremophile – creatures Miller discusses in his new book

"If I mentioned that I was a scientist at a party, people would turn and just stop"

What do you think of the UFO stories?
They fascinate me as much as the science and I'm a sucker for a good UFO tale. I just don't think they are true in the literal sense. Maybe in a metaphorical sense they are. They can make me laugh.

Do you think that your background in comedy is helpful when dealing with a subject like extraterrestrial life?
Perceptions are changing. It used to be that no one was interested in science at all. When I did my degree, if I mentioned that I was a scientist at a party, people would turn and just stop. You might as well have said you had soiled your underpants. They would sort of walk away and make no pretence of their disgust and now that has changed and I don't know why. Maybe it goes in cycles.

Why do you think that is?
I think the internet helps and the availability of scepticism. Technology has really won the argument and it may not have set the culture alight but it really has provided value that can't be questioned. Most importantly, humans are really curious as a species and this is what we do. We try and find answers to things. We try and find out what's out there and not only do we want to know what's out there in terms of what does the nearest planet look like, can we go there and can we live there, but we want to find out what we don't know. You can't suppress that forever.

Would you like to go into space?
Yes, I mean sure, why not. Is that like saying, do you want to date Miss World. Yes, why not?

*The Aliens Are Coming!
The Exciting And Extraordinary Science Behind Our Search For Life In The Universe by Ben Miller is out now in paperback.

FOCUS ON

SIGNS OF RECENT WATER ACTIVITY FOUND ON RED PLANET

Martian water played a major role in creating intriguing surface features on miniature sand dunes

Reported by Sharmila Kuthunur

Scientists studying data from China's Zhurong rover have for the first time found cracked layers on tiny Martian dunes, implying that the Red Planet was a salt-rich watery world as recently as 400,000 years ago. Since landing in Mars' northern hemisphere in May 2021, the rover has rolled close to four nearby crescent-shaped dunes in the Utopia Planitia region to investigate their surface composition. All four of the miniature, wind-formed geological features are coated with thin, ubiquitously fractured crusts and ridges that formed thanks to melting small pockets of 'modern water' sometime between 1.4 million years and 400,000 years ago. "This means a more recent time in Martian history," Xiaoguang Qin, a scientist at the Chinese Academy of Sciences in Beijing, said.

Scientists have long thought that Mars harboured liquid water about 3 billion years ago, but dramatic climate changes froze much of it as ice, now locked in poles, and left the bulk of the planet parched. The dunes Zhurong explored are close to its landing site in the planet's northern hemisphere – far from the North Pole – and just shy of 50 to 100 feet (15 to 30 metres) long and about 3 feet (1 metre) tall. Findings from analysing images and data sent home by Zhurong and its Tianwen-1 orbiter companion show that appreciable amounts of water from the icy polar regions wafted to lower latitudes a few million years ago, settling on the Utopia Planitia dunes.

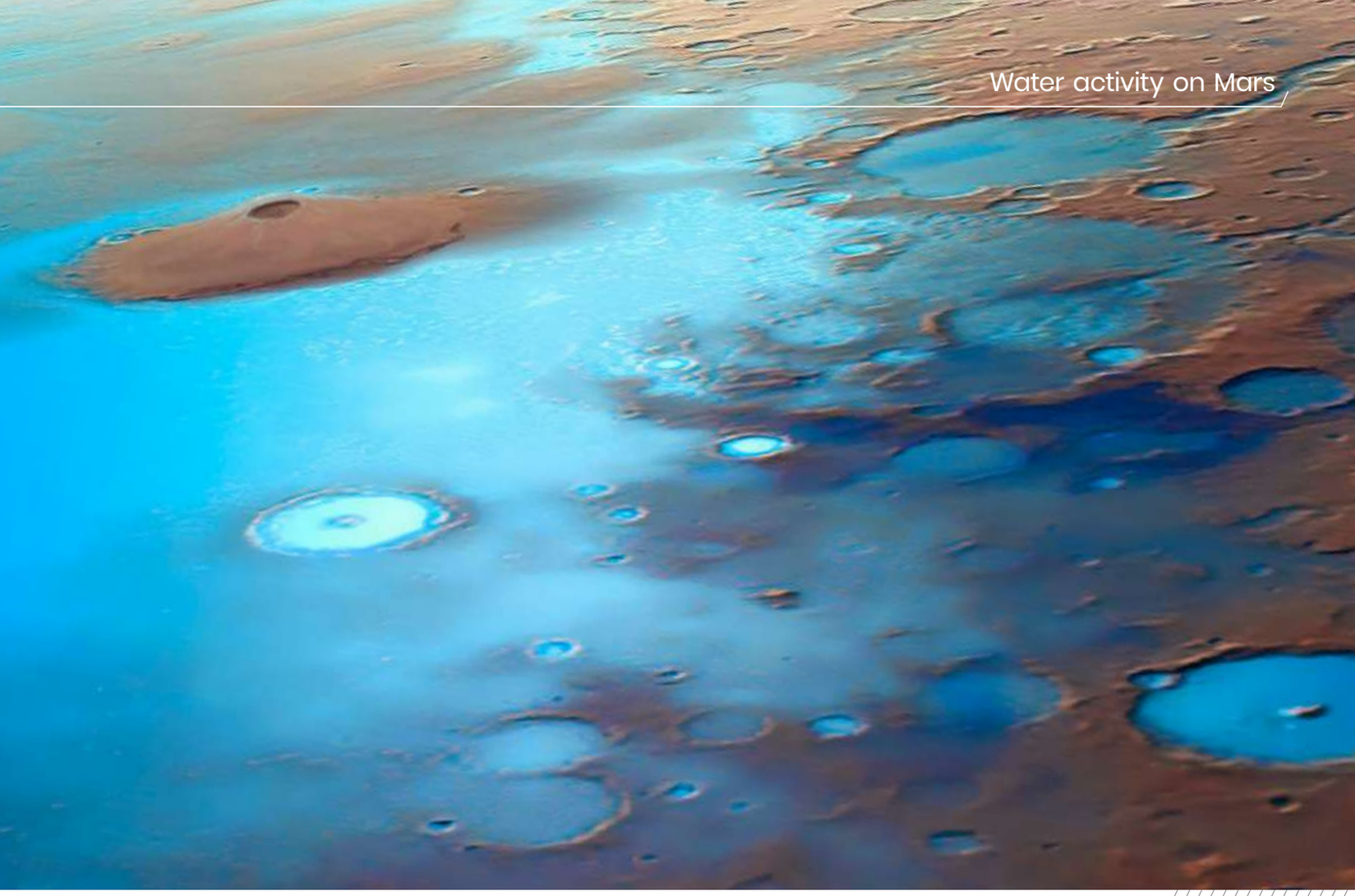
When Zhurong ventured close to its target dunes, which are pint-sized compared to the massive two-storey ones that NASA's Curiosity rover studied elsewhere on Mars, the laser-induced breakdown spectrometer (MarSCoDe) instrument on board the rover zapped sand grains into millimetre-sized particles. Their chemical makeup revealed hydrated minerals like sulphates, silica, iron oxide and chlorides. According to the study team, these minerals formed in the presence of water at low latitudes in the late Amazonian era on Mars, which scientists previously thought was bone-dry.

Researchers say water vapour travelled from Martian poles to lower latitudes like Zhurong's spot a few million years ago, when the planet's polar ice caps released high amounts of water vapour thanks to a different tilt that had Mars' poles pointed more directly towards the Sun. Frigid temperatures on the wobbling planet condensed the drifting vapour and dropped it as snow far from the poles.

An artist's impression of water on ancient Mars

Zhurong takes a selfie with the Tianwen-1 lander

> "The phenomenon should be applicable at a large fraction of Mars' surface"
>
> **Xiaoguang Qin**



Mars' tilt changes over a 124,000-year cycle, so "this offers a replenishing mechanism for vapour in the atmosphere to form frost or snow at low latitudes where the Zhurong rover has landed," Qin said. But "no water ice was detected by any instrument on the Zhurong rover."

Instead, in the same way that salting roads on Earth melts icy patches during storms, salts in Martian sand dunes warmed the fallen snow and thawed it enough to form saltwater. The process also formed minerals such as silica and ferric oxides, which Zhurong spotted. The saltwater, however, didn't stay around for long. Temperatures on Mars swing wildly and spike in the mornings between 5am and 6am, so the saltwater evaporated and left behind salt and other newly formed minerals that later seeped between the dune's sand grains, cementing them to form a crust.

The crust that formed atop the dunes, which runs just 0.5 inches (1.25 centimetres) to 3 inches (1.7 centimetres) deep, likely materialised as quickly as a year, because the loose dunes wouldn't stay in place long enough to solidify across millennia. It then cracked as high temperatures dehydrated it so much that they "should be hard and resist wind erosion," Qin said. "The phenomenon was documented at one site, but it should be applicable to a fairly large fraction of Mars' surface at similar latitudes," Manasvi Lingam, an assistant professor of astrobiology at the Florida Institute of Technology, said.

Since Zhurong, which is now suffocating under dust-coated solar panels, has revealed water activity on top of and inside Martian dunes, researchers of the new study propose future missions to search for salt-tolerant microbes, perhaps like brine shrimp residing in Utah's Great Salt Lake in the United States.

© Getty: China News Service

SPECIAL REPORT

WHAT'S NEXT FOR VIRGIN ORBIT?

The company set up by Sir Richard Branson to send satellites into orbit from a plane is facing an uncertain future, and that could have repercussions for the UK's space ambitions

Reported by David Crookes

When 2,500 onlookers began to gather in Cornwall one calm Monday evening in January, nobody really expected the night to end in failure. UK politicians were heralding the start of a new space era for Britain; those working at Spaceport Cornwall said it was transforming access to space across the world; and Dan Hart, CEO at Virgin Orbit, believed it would "soon establish the UK as the first nation with the capability to launch to orbit from western Europe." But then the worst happened.

The Start Me Up mission launched by Virgin Orbit from Spaceport Cornwall on 9 January 2023 initially appeared to have been successful. A modified Boeing 747 plane called Cosmic Girl took off horizontally with a LauncherOne rocket attached to its wing shortly after 10pm and headed across the Atlantic towards the southwest coast of Ireland. The idea was that upon reaching 35,000 feet, it would unleash the rocket into orbit and send a payload of nine satellites into space, five of which were from the UK.

And yet – despite Virgin Orbit's initial tweet suggesting that the rocket had made it to orbit – all did not go to plan. Although the mission, funded by the UK Space Agency, dropped from the plane as planned and the first stage of the rocket successfully burned as expected, it soon became clear that something had gone wrong. The first tweet was swiftly deleted and another was issued by the company. "We appear to have an anomaly that has prevented us reaching orbit," it said. "We are evaluating the information."

While the news was undoubtedly disappointing – "space is hard," said Melissa Thorpe, head of Spaceport Cornwall, in a statement the following day – the initial reaction was one of brushing down and starting over. There was a sense that it was a mere setback that would be overcome. "We will work tirelessly to understand the nature of the failure, make corrective actions, and return to orbit as soon as we have completed a full investigation and mission assurance process," Hart said at the time.

START ME UP: HOW IT HAPPENED

14 July 2014
Newquay Airport announces its bid to become a UK spaceport for satellite launches.

16 July 2018
Virgin Orbit signs a deal with Spaceport Cornwall, aiming to launch satellites using innovative horizontal launch technology.

4 June 2019
The UK government and Cornwall Council say they will invest £20m into Spaceport Cornwall to create a base for Virgin Orbit.

25 May 2020
The first Virgin Orbit launch from Mojave Air and Space Port California encounters an anomaly after a few seconds and fails.

17 June 2020
The UK and the US sign a Technology Safeguards Agreement, making it easier for rocket hardware to be shipped between the countries.

17 January 2021
With 10 cubesats on board, the second launch by Virgin Orbit from California is a resounding success.

25 January 2021
Spaceport Cornwall, buoyed by the successful Virgin Orbit launch in the US, hopes for a UK launch in 2022.

30 June 2021
The Tubular Bells Part 1 mission successfully carries seven satellites into Low Earth Orbit from California.

13 January 2022
Above The Clouds also succeeds in sending satellites into orbit.

2 July 2022
Straight Up is applauded for launching seven satellites into orbit for the US Space Force.

2 September 2022
The LauncherOne rocket leaves Virgin Orbit's factory in Long Beach, California, USA.

9 October 2022
The first of Virgin Orbit's hardware for the launch makes its way from California to Cornwall, UK.

11 October 2022
The equipment arrives at Spaceport Cornwall, followed by the Ground Support Equipment and the rocket.

4 November 2022
The government's Science and Technology Select Committee is concerned that licences for the satellite launch is taking too long.

9 January 2023
The first ever satellite mission launched from UK soil ends in failure when a rocket fuel filter becomes dislodged.

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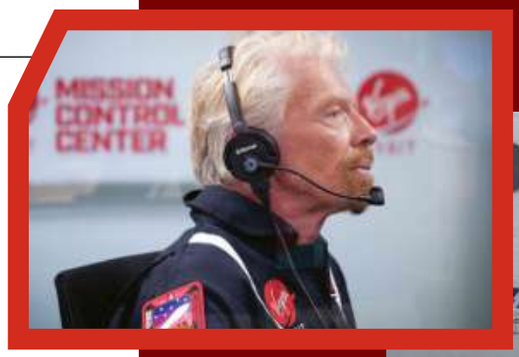


Sir Richard Branson spent more than $1 billion on Virgin Orbit, believing the use of modified planes would cut the costs of launching satellites

Employees inspect the 'Cosmic Girl' Boeing Co. 747 launch aircraft at Spaceport Cornwall

Cosmic Girl arrives at Spaceport Cornwall, the former RAF military airport that became a civil airport in 2008 (Cornwall Airport Newquay) and the first licensed UK spaceport

Since then, however, there have been more twists and turns. By March, Virgin Orbit had cut 85 per cent of its workforce after failing to secure fresh funding and, in April, it filed for US Chapter 11 bankruptcy protection, intending to find a buyer. Given that Virgin Orbit is the only company with a contract to launch from Spaceport Cornwall, the news appeared to be something of a setback for UK space. Many questions about the fledgling sector's future have inevitably been asked.

Today, we know a bit more about what happened that night. On 12 April, the company completed its month-long, full-scale test series and revealed that the investigation had focused on the filter in the fuel tank outlet. Tests suggested the filter had dislodged in the fuel line of the upper tank Newton-4 engine, causing it to prematurely shut down. But by redesigning the filter, the problem should not reoccur if, as planned, Virgin Orbit ends up flying its next rocket from Mojave Air and Space Port in California later this year. The thing is, the future is not nailed on for the firm.

Virgin Orbit spun out of Virgin Galactic – the venture that aims to play a key part in future space tourism – back in 2017. Its strong selling point was the ability to provide a piggy-backing horizontal system that could be fitted with a rocket and fly over adverse weather from runways at adapted airports and save on fuel costs. Yet over the past six years, reports suggest it has burned through money. It had a net loss of $43.6 million in the third quarter of 2022, for example, which was more than in the same period the year before. It also began to struggle to attract interest: it was listed on New York's Nasdaq stock exchange in December 2021, yet raised less than half the $483 million it had hoped for. Space is hard, but it sure is expensive.

Even so, Virgin Orbit – 75 per cent of which is owned by Virgin Investments – has achieved success during its short lifespan so far. Although its first launch in May 2020 failed, it went on to enjoy a run of four triumphs, each from the runway at the Mojave Air and Space Port. The company deployed 10 CubeSats into Low Earth Orbit for NASA in January 2021, fired a commercial payload into space six months later, delivered seven CubeSats in January 2022 and carried seven payloads under a contract with the US Space Force in July. In that sense, it proved that horizontal launches work, and everyone was set to expand the operation internationally.

By hooking up with Spaceport Cornwall, the aim was to show that such launches could take place elsewhere and allow other countries the opportunity to become key space players. Virgin Orbit proudly told interested parties that it could help nations turn existing airports with sufficiently long runways into spaceports with no new construction and no significant environmental impact. It has been a hugely attractive proposition – a prestigious money saver in many respects, too.

Since the UK is among the world's leading builders of small satellites, the tie-up certainly made sense for all parties. But with spending rampant and too little investment incoming at Virgin Orbit, it appeared only a matter of time before – as Maxime Puteaux, a principal advisor at space analysts Euroconsult, says, "The company was in reach of the end of the financial runway."

"Having launched six times, failing twice, Virgin Orbit was running out of cash without bumping up the launch rate," Puteaux tells **All About Space**, going on to say that the company needed to fly Cosmic Girl more often. But while there was an intention to do just that – the third quarter 2022 financial results clearly states the top priority for 2023 was to "more than double 2022 launch rate"

"Having launched six times, failing twice, Virgin Orbit was running out of cash without bumping up the launch rate"

Maxime Puteaux

followed by a desire to "increase revenue per launch" – those ambitions should really have come to fruition earlier.

"Virgin Orbit found itself in trouble after performing several launches, which is quite unusual in this industry," Puteaux continues. "Usually companies will falter amid the development of a product because they're experiencing difficulties and running out of money, but Virgin Orbit was just unable to ramp up production and the launch rates."

Puteaux blames some of this on the nature of the company – one headed by billionaire Richard Branson that benefitted from deep-pocketed investors. "There wasn't the same incentive to move faster compared to cash-strapped companies," Puteaux argues. At the same time, he claims there was political pressure on Virgin Orbit to deliver the UK launch on a given date. "Politics, launches and reliability do not mix well," he says.

To be clear, the failed launch in the UK is not to blame for Virgin Orbit's demise. Neither, says Puteaux, does the plight of the company reflect badly on the UK space industry. "Virgin Orbit does not have a UK footprint," he argues. "It's a US company which offered the UK government the fastest way to commit to a launch on British soil. From an industry perspective, it wasn't building a UK ecosystem."

In that sense, it's just an unfortunate sequence of events that those in the UK will be working hard to overcome. But quite what happens next is not entirely clear. While Virgin Orbit (should the company be rescued) plans to increase its workforce to 275 employees by the end of this year, then launch much more regularly than it had before during 2024, it's too early to know whether or not the UK would stand to benefit, or whether or not this would happen. As it stands, Virgin Investments is providing $31.6 million in new money to help Virgin Orbit find a buyer, and the company says it's focused on a swift conclusion.

As far as the UK Space Agency is concerned, however, this can only be seen as a learning curve. Yes, it's a setback, but the agency is up for the challenge, having already shown great ambition by investing in the first ever rocket launch from British soil. "Compared to the UK-led Black Arrows launches from Australia in the Sixties and Seventies, this development of physical launch capabilities in the UK meant venturing into new territory," affirms the UK Space Agency's director of commercial spaceflight, Matt Archer. "This has included the development of a fully operational spaceport in Newquay, Cornwall; a physical rocket lift-off; and a new licensing process

THE MISSION OF MANY FIRSTS

The Virgin Orbit launch held so much promise for the UK

First orbital launch from a UK spaceport

First ever satellite mission from the UK

First commercial launch from western Europe

First spaceport to be created in the UK

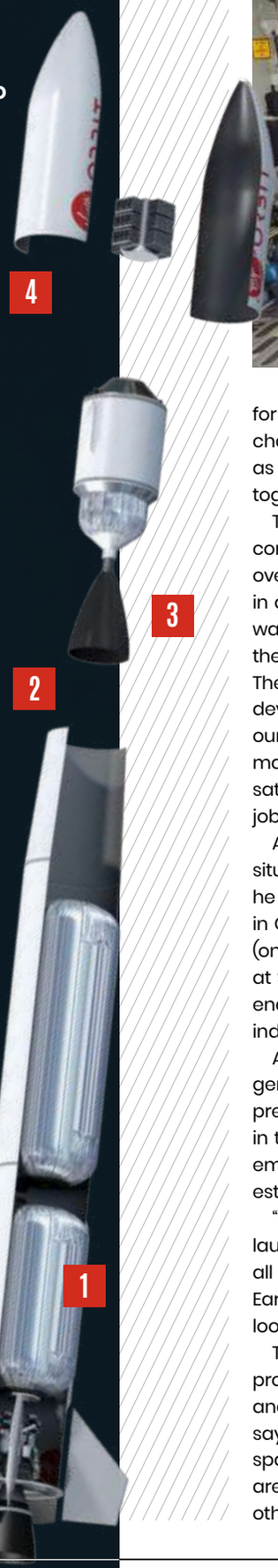
First satellite built in Wales

First international launch for Virgin Orbit

© Virgin Orbit; Getty

LAUNCHING INTO ORBIT

How LauncherOne is designed to send satellites into space – and what went wrong



1 First Stage

LauncherOne (a 21-metre (70 feet) long, two-stage orbital launch vehicle) is released from Virgin Orbit's Cosmic Girl plane at about 10,600 metres (35,000 feet) and free falls for four seconds. The NewtonThree engine in this part of the rocket kicks into action, thrusting it skyward at an angle of 27 degrees.

2 Second stage

Having reached a maximum speed of 12,800kph (8,000mph), the fuel is spent and the first stage detaches. The NewtonFour engine in the second stage of the rocket then powers up and it can reach a speed of 28,000kph (17,500mph). It allows circularisation of the desired orbit.

3 A dislodged filer

It's here where the mission failed! According to Virgin Orbit, which conducted a month-long investigation into the cause, a filter in the fuel line became dislodged and travelled into the NewtonFour engine, causing it to prematurely shut down. It meant it failed to reach orbit.

4 Releasing the payload

If it had succeeded, the rocket's fairing would have opened, revealing the payload – in the case of the Cornwall launch that would have been nine satellites. The payload would have been ejected into its final orbit, with the second stage then descending back to Earth where it would burn in the atmosphere.

for the Civil Aviation Authority. This naturally presented challenges, and we know the mission did not end as hoped, but the vast majority of these steps came together successfully."

There is, it would seem, a strong determination to continue. "Of course, we were disappointed that the overall mission was not a success – a lot of people put in a huge amount of time and effort, so it was difficult to watch things not go to plan." Archer adds. "But despite the setback, we will progress and learn from this mission. The government remains committed to supporting the development of a dynamic UK spaceflight sector and our focus is on supporting multiple projects designed to make the UK the leading provider of commercial small satellite launches in Europe by 2030, generating more jobs and growth across the country."

Archer wouldn't comment on Virgin Orbit's specific situation – "That's a commercial matter for Virgin Orbit," he said – but he emphasised that aside from the facility in Cornwall, there are two new spaceports in Scotland (one under construction at SaxaVord and one set to start at Sutherland) anticipating launches in 2024. To that end, "The outlook is positive," he affirms. The UK space industry is also in good health.

According to the latest figures, UK space organisations generated £17.5 billion in 2021, up from £16.5 billion the previous year. There are also 1,590 space organisations in the UK (up from 1,293) and about 48,800 people are employed by the sector, which in turn supports an estimated 126,000 UK jobs across the wider supply chain.

"Globally, there were more than 1,700 small satellites launched in 2021, representing more than 90 per cent of all spacecraft launched that year, predominantly into low Earth orbit," Archer continues. "That is the market we are looking to access."

There is also optimism at Spaceport Cornwall – a project funded by £7.85 million of government cash and £12 million from Cornwall Council. While Puteaux says, "Like with any other airport looking to become a spaceport through Virgin Orbit, without Virgin Orbit, they are no more than an empty airstrip", discussions with other operators are underway. It's become a space

The LauncherOne rocket was transported on an RAF C17 Globemaster ahead of the Cornwall launch

Many deals were struck ahead of the launch, including one with Space Forge which created the first Welsh-developed satellite

hub (there are more than 70 space-linked businesses in the area), contributing about £200m each year to the Cornish economy.

"Spaceport Cornwall continues to operate with several future operators in various stages of discussion and other on-site activity underway," Melissa Quinn, head of Spaceport Cornwall, tells us. "As the UK's only licensed spaceport, we continue to grow the cluster in Cornwall, recently opening a new space operations facility to support global space and satellite businesses and inspiring local school children into STEAM through our outreach programme."

Cornwall's new Space Systems Operations Facility (SSOF) has attracted interest from 10 organisations; Avanti Communications, Goonhilly, KISPE, D-Orbit, Exobotics, Expleo, Geospatial Ventures, Satellite Applications Catapult, Space Skills Alliance and Intelligent AI. It has labs, collaboration space, office space and hot-desking. There is also a clean room, so the spaceport can have satellites built, integrated and launched.

"Combined with Spaceport Cornwall's Space Systems Integration Facility, the SSOF completes the Centre for Space Technologies, a £5.6 million project funded by ERDF and Cornwall Council," Quinn says. "We are also in talks with other launch operators, including Sierra Space, to continue the next steps in our journey to become a potential return side for their Dream Chaser."

And yet the failure of the Virgin Orbit mission still hangs, especially since finding an alternative launch operator is no easy task. Northrop Grumman is among those able to launch rockets from an aircraft (it first launched the Pegasus rocket from beneath a NASA B-52 aircraft from the Dryden Flight Research Center in California in 1990, and there have been 45 missions since). But it's expensive and much of the focus surrounding launches seem to be the vertical rather than horizontal method.

"I'm still not convinced of the airlaunch solution, even though it allows for reactive launches on demand and the design is purported to be more efficient and flexible," says Puteaux. "That's not to say there is no room for Virgin Orbit in the market, but the company will need to redesign and kill the costs, because they were burning cash at a worrying rate."

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

© Virgin Orbit; Getty

INSTANT EXPERT

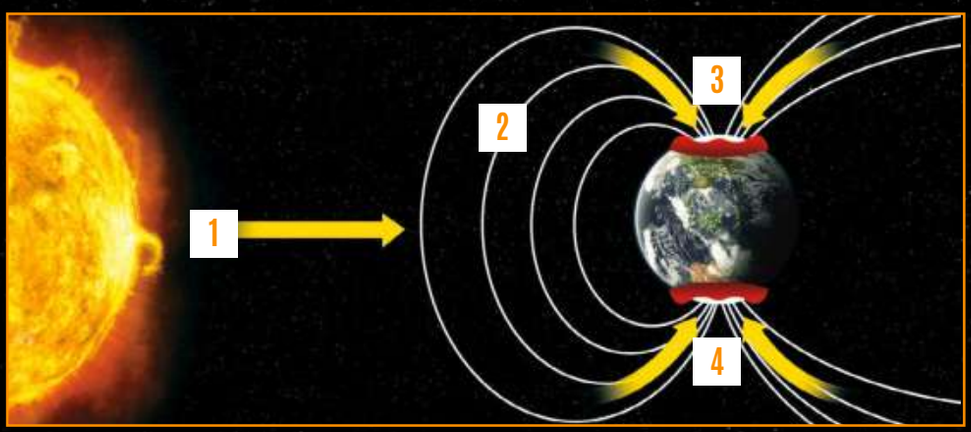
HOW ARE AURORAE FORMED ON OTHER PLANETS?

The northern and southern lights occur when the solar wind affects our atmosphere, but this can happen on other worlds too

The shimmering northern lights, or aurora borealis, are a natural light show that occurs in a loop around the poles. The southern version is known as aurora australis. Aurorae occur when charged particles emanating from the Sun in the solar wind crash into the upper atmosphere. A mixture of electrons, protons and helium nuclei, they lose energy as they collide with atmospheric gas molecules. These molecules become ionised, meaning some of their electrons are pulled away, and the gases form a glowing plasma. The gas mix governs the colours we see. Red is generated by low concentrations of oxygen at high altitudes. This changes to green as oxygen density increases, with blue generated by nitrogen. Pink, yellow and orange have all been observed, presumably due to the layering of different amounts of red, green and blue. Intriguingly, because our eyes construct our colour perception from red, green and blue-sensing cells, aurorae could form any colour at all depending on the combination of the primary gas colours. Aurorae are clustered around the poles because Earth's magnetic field dips into the surface. There, particles are repelled from lower latitudes and funnelled into the atmosphere in loops around both poles. But these bands can grow with strong solar storms, occasionally bringing aurora as far south as southern Britain and northern France.

Other planets in the Solar System have varying combinations of magnetic fields and atmospheres, but we've found aurorae there too. The most spectacular display is on Jupiter, with 14 times the magnetic field of Earth. As well as the solar wind, it has its moon Io, the most volcanically active body in the Solar System, cutting through its magnetic field while spewing out more gases. Indeed, aurorae have been observed around Io, Europa and Ganymede because of their complex interactions with Jupiter.

Saturn's aurorae have been captured by a number of spacecraft – even from the Hubble Space Telescope in Earth orbit – but the energy characteristics and gases involved produce ultraviolet light that would be invisible to humans. Despite Mars' limited magnetic field and atmosphere, Martian aurorae have been observed by the European Mars Express probe, clustered around magnetic variations in the crust. Most curious of all, however, are the Venusian aurorae. Venus has no magnetic field, but Mars Express' Venusian twin found magnetic effects produced by the solar wind interacting with the charged outer layer of the atmosphere. This seems to produce random patches of light, as they aren't fixed to magnetic poles.



1 Solar wind
A mixture of free electrons, protons and helium nuclei streams out of the Sun constantly, increasing in density with solar storms.

2 Earth's magnetic field
Earth's magnetic field is believed to be generated by the molten iron circulating around the core.

3 Magnetic poles
Because the field dips into our planet at the poles, charged particles are funnelled into the atmosphere there.

4 Ionisation
As solar wind particles hit gas molecules on Earth, they dump their energy into them, forming the glowing auroral plasma.

BIO
ROBIN HAGUE
Hague is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

5 Auroral noise
Sounds have been reported along with aurorae; it's believed this may be due to the electric field causing charged molecules in the lower atmosphere to vibrate.

6 Induced currents
Aurorae can induce electrical currents as they interact with the atmosphere. It was reported in the 19th century that telegraph networks could even draw power from them.

7 Colour layers
Diffuse oxygen produces red light in the highest aurorae, changing to green as density increases. Nitrogen generates blue light lower down.

8 Altitude
Aurorae occur between 90 and 150 kilometres (56 and 93 miles) altitude, straddling the boundary of space but below the orbit of the International Space Station.

"Other planets have varying combinations of magnetic fields and atmospheres, but we've found aurorae there too"

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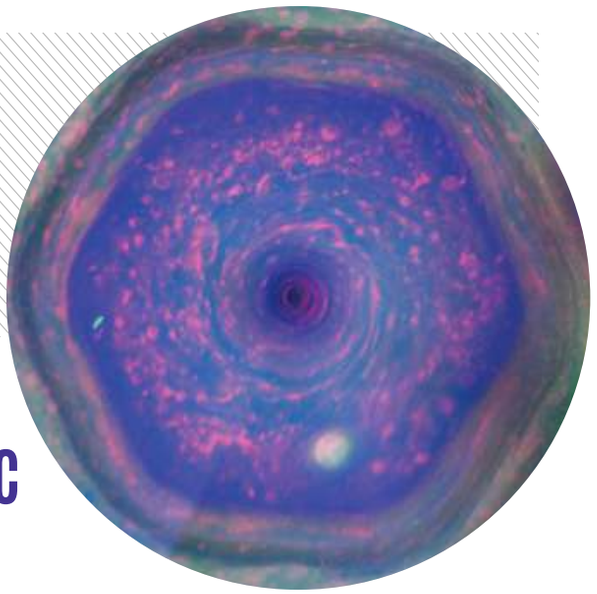
THE FACE ON MARS AND OTHER SHAPES IN SPACE

Humans keep finding patterns among the stars, helping us locate and recognise astronomical wonders

Written by Nikole Robinson

Since the first ancient humans turned their gaze to the skies above, civilisations began familiarising themselves with the inky blackness of the night sky using the patterns they saw in it – much like a join-the-dots puzzle of the points of light we now know to be stars, nebulae and galaxies. These patterns resembled recognisable objects or animals within different cultures and were used to track the seasons and for navigation. Modern astronomy uses a very similar system, with 88 official constellations used to divide the sky into sections, many based on those used by past cultures and explorers.

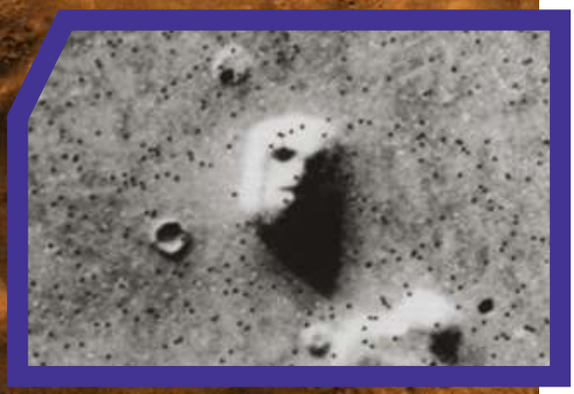
Looking further into the cosmos with ever-improving telescope technology has shown that there are shapes and patterns to be found beyond the constellations as well, with wispy filaments of gas and dust, clusters of stars and even the surfaces of planets surprising us with something familiar so far from home.



KALEIDOSCOPIC SATURN

10 December 2012

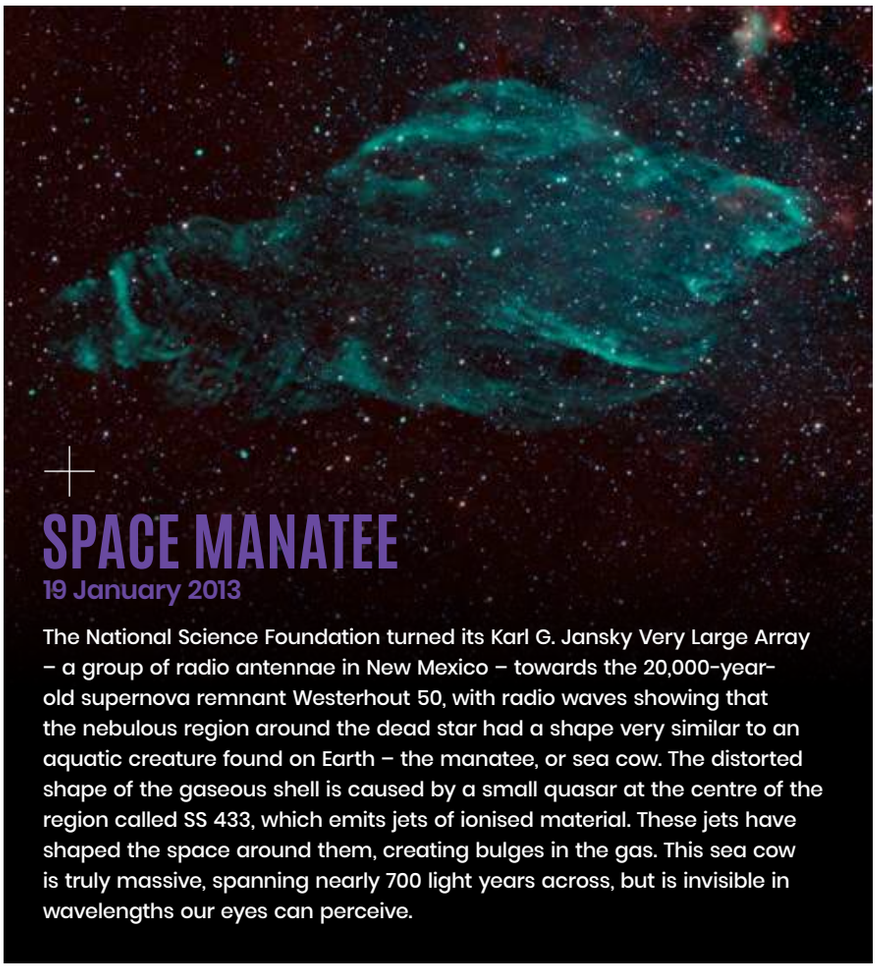
The Voyager program was humanity's first real chance to get an up-close look at the giant outer planets of the Solar System, and the twin spacecraft absolutely delivered on the science. Voyager 1 data of Saturn showed the Ringed Planet had a strange phenomenon at its north pole – a hexagonal cloud formation. When Cassini was sent to the Saturnian system decades later, it was prepped to get a closer look at this odd planetary geometry. Eight frames were captured from above Saturn's north pole over a ten-hour period to capture the motion of air around the pole that creates this shape, revealing a central hurricane at the northernmost point of the planet.



MARTIAN MASK

25 July 1976

When NASA scientists were inspecting photos beamed back by Viking 1 and 2 in the 1970s, the last thing they expected to see was a stony face staring back at them. This two-kilometre (1.2-mile) wide feature watched its observers from a region of Mars called Cydonia. Taking into account the low camera quality available in the 1970s, the face was quickly dismissed as a trick of the light by Viking project scientist Gerry Soffen and his colleagues. More recent visits by advanced spacecraft like the Mars Reconnaissance Orbiter have confirmed the mask-like structure to be a mesa, a flat-topped area of elevation which is common in the Cydonia region of Mars.



SPACE MANATEE

19 January 2013

The National Science Foundation turned its Karl G. Jansky Very Large Array – a group of radio antennae in New Mexico – towards the 20,000-year-old supernova remnant Westerhout 50, with radio waves showing that the nebulous region around the dead star had a shape very similar to an aquatic creature found on Earth – the manatee, or sea cow. The distorted shape of the gaseous shell is caused by a small quasar at the centre of the region called SS 433, which emits jets of ionised material. These jets have shaped the space around them, creating bulges in the gas. This sea cow is truly massive, spanning nearly 700 light years across, but is invisible in wavelengths our eyes can perceive.

© NASA; Alamy

TADPOLE TRAIL

21 June 2021

420 million light years away in the constellation of Draco lies a streamer of stellar material leading away from the galaxy UGC 10214, the Tadpole Galaxy. This trailing tail measures an enormous 280,000 light years long and was displaced by a gravitational interaction with a passing galaxy around 100 million years ago. This event caused mass star formation within the galaxy and its tail, which exhibit many clusters of bright, blue stars. Some of these clusters of hot young stars include over a million individual members. The tail will likely fade away in time through the birth of new stars, but the clusters within it may become dwarf galaxies around the galactic head of the tadpole.

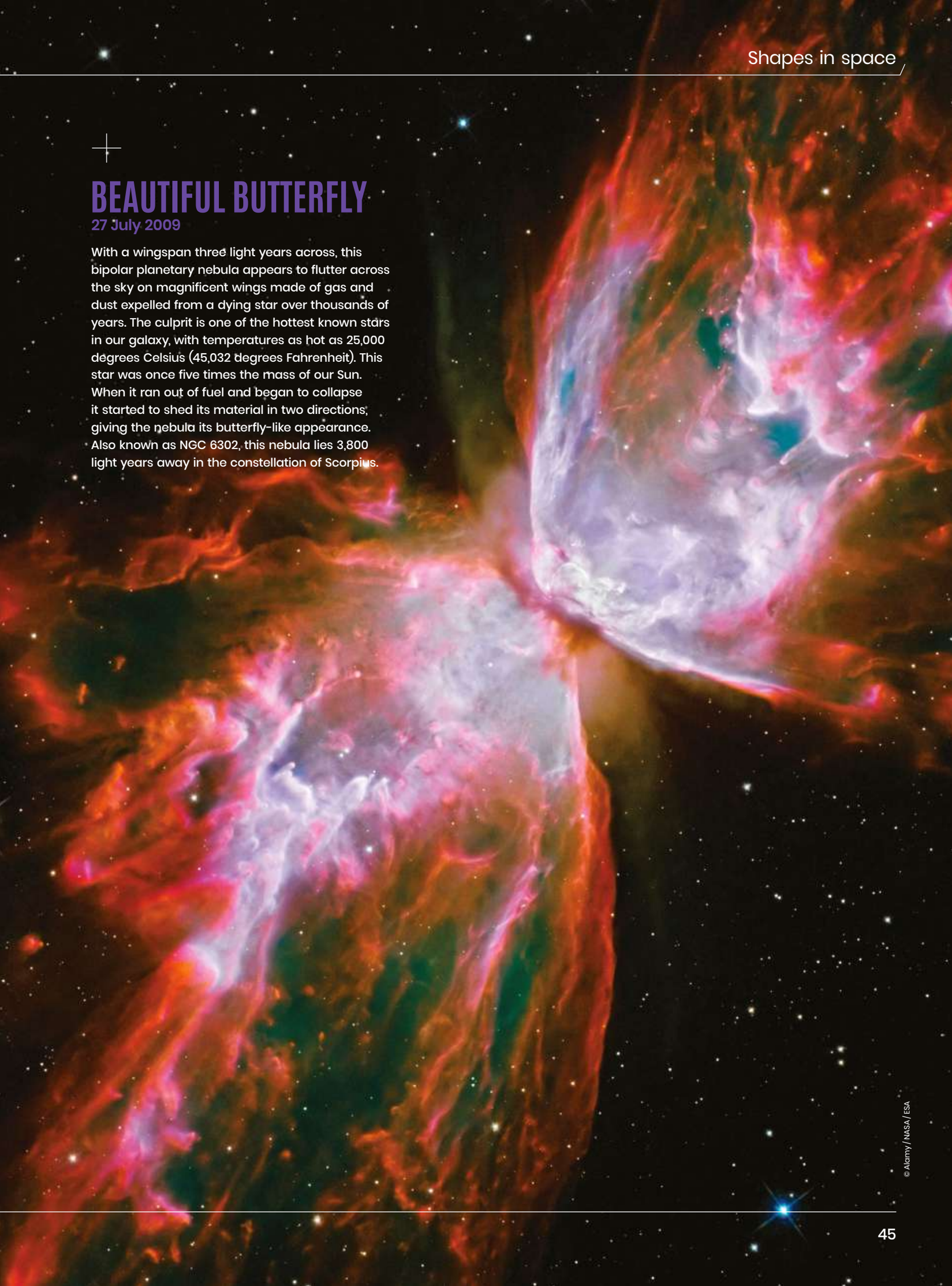
CAROLINE'S ROSE 15 November 2017

This stunning star-studded open cluster was discovered by Caroline Herschel in 1783 and is said to compare to the swirling patterns of rose petals found atop the thorny plant. The stars of the cluster are thought to be around 1.6 million years old and would have all burst to life around the same time from the same star-forming cloud. However, many of its stars are now in different evolutionary stages due to their varying sizes and temperatures. Some members remain on the main sequence, while others have already swollen to become red giants. This floral cluster spans around 50 light years across.

CACKLING WITCH

11 December 2006

This reflection nebula's gas and dust is lit up by the bright star Rigel in Orion, giving it its ghostly glow. As Rigel is an extremely bright blue-white supergiant, the gaseous region also appears blue as it bounces the star's colour back. The dust grains in the nebula also reflect blue light much more effectively than red, further deepening the colour. This is the same process that makes the daytime sky above our planet appear blue, though this is done by particles of nitrogen and oxygen in our atmosphere rather than grains of dust. The pointed 'chin' and 'nose' conjure images of an old crone staring into the stars, giving the object its name.



BEAUTIFUL BUTTERFLY

27 July 2009

With a wingspan three light years across, this bipolar planetary nebula appears to flutter across the sky on magnificent wings made of gas and dust expelled from a dying star over thousands of years. The culprit is one of the hottest known stars in our galaxy, with temperatures as hot as 25,000 degrees Celsius (45,032 degrees Fahrenheit). This star was once five times the mass of our Sun. When it ran out of fuel and began to collapse it started to shed its material in two directions, giving the nebula its butterfly-like appearance. Also known as NGC 6302, this nebula lies 3,800 light years away in the constellation of Scorpius.

© Alamy / NASA / ESA

FELINE EYE

9 September 2004

Nicknamed the Cat's Eye Nebula, NGC 6543 is one of the most complex planetary nebulae ever discovered, making it a prime target for study. Observations have revealed detailed and intricate structures within the expelled gas and dust around the central stellar remnant, such as chunky knots and shells of gas. The concentric rings that this Hubble image highlights show that the dying star at the centre distributed its material into the cosmos in several separate bursts spaced over a thousand years apart. Studying planetary nebulae is important because it gives us a window into what will happen to our Sun when it runs out of fuel in around 5 billion years.

BEEHIVE CLUSTER

30 April 2022

Messier 44 is one of the closest star clusters to our Solar System, making observing it a treat for expert and amateur astronomers. The open cluster of around 1,000 stars lies just 600 light years away from Earth in the constellation of Cancer, and its stellar population is believed to be 600 million years old. Though many people call this grouping the Beehive Cluster, others call it Praesepe, which is Latin for manger. Due to its naked-eye visibility under dark skies, the Beehive Cluster has been observed since antiquity, though it wasn't until telescopes were invented that its individual stars were resolved.

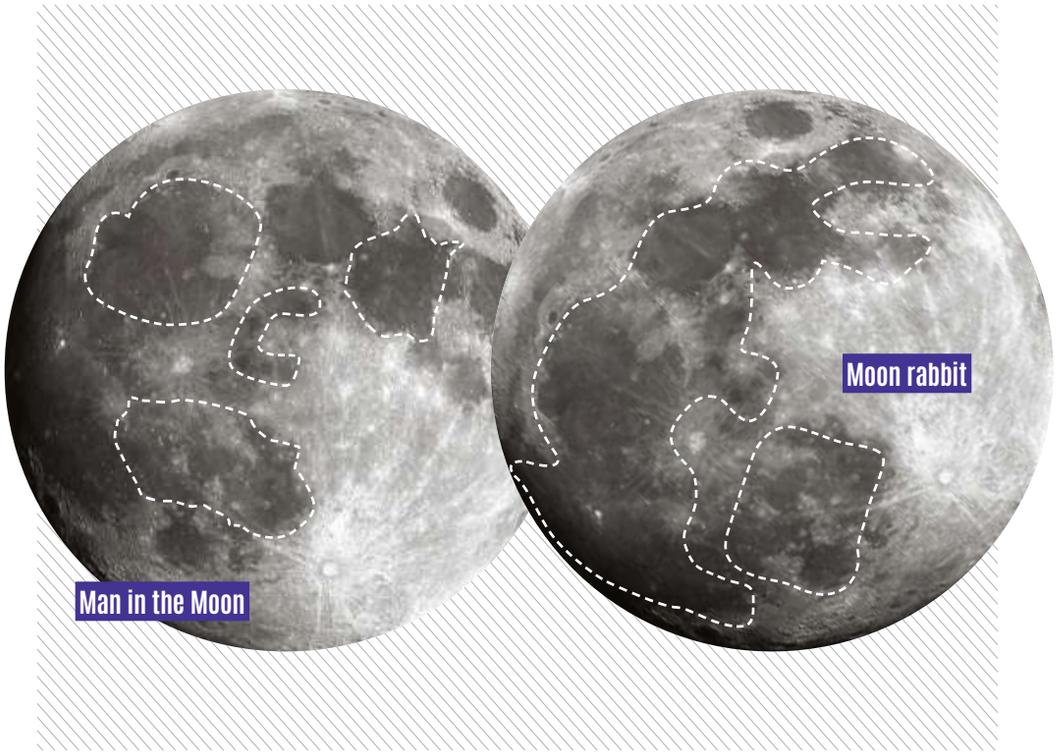
PENGUIN AND EGG

31 January 2018

This unusual pair of interacting galaxies is collectively known as Arp 142 and resembles a penguin taking care of its egg. The penguin, NGC 2936, likely used to be a standard spiral galaxy before the close approach began to deform it. The egg, NGC 2937, is an older elliptical galaxy. The two galaxies are moving closer together, and will one day merge into one big galaxy. This colourful image was created by combining visible-light data from the Hubble Space Telescope with infrared observations made by Spitzer. Combining data from telescopes with different capabilities allows astronomers to make new findings about interesting targets like galaxies on a collision course.

RORSCHACH MOON

The most familiar sight in the night sky, humans see the Moon all the time as it orbits our planet. However, viewing it from different places on Earth changes how the maria and craters on its face are orientated, and this has led to different interpretations of what our natural satellite resembles. The most common Western perception of the Moon viewed from the Northern Hemisphere is a face formed by its dark patches of lava, with Mare Imbrium and Mare Serenitatis forming its eyes, Sinus Aestuum the nose and Mare Nubium and Mare Cognitum a gaping mouth. East Asian moongazers of the past saw a rabbit instead, giving rise to folklore about a Moon rabbit that pounded mochi or made elixir with a pestle and mortar.



INTERSTELLAR CIGAR

19 October 2017

In 2017, a weird object made headlines thanks to its origin from beyond our Solar System, discovered when scientists traced its path backwards based on its trajectory around the Sun. It turned out that the object wasn't gravitationally bound to our star, giving it away as an interloper. Dubbed 'Oumuamua, just as strange was the object's elongated shape – possibly ten times as long as it was wide – with many an artist's conception giving it the appearance of a rocky cigar. 'Oumuamua made its closest approach to Earth at about 24 million kilometres (15 million miles) on 14 October 2017 and is currently on its way back out of the Solar System... likely never to return.

© Alamy / NASA

THAT'S NO MOON

13 February 2010

Anyone with an interest in science fiction will know why this tiny moon of Saturn drew attention in 2010 when the Cassini spacecraft made a close approach of Mimas, flying within 9,500 kilometres (5,900 miles) of its heavily cratered surface. The giant crater Herschel – named after the moon's discoverer and measuring a third of the moon's diameter – gives this moon the appearance of the planet-destroying Death Star from *Star Wars*. If Earth had a crater the equivalent size, it would cover an area bigger than Australia. Scientists are curious to learn how the giant impact that formed this crater didn't shatter Mimas into pieces, as would be expected from its size.

GALACTIC HAT

2 October 2003

Messier 104 is a peculiar galaxy we can only view side-on relative to Earth. Its bright central bulge and dark outer dust lane bring to mind a wide-brimmed Mexican hat, and this resemblance is where the galaxy got its nickname: the Sombrero Galaxy. Although it lies 31 million light years away, the object's bright magnitude of +0.8 means even small amateur telescopes are able to resolve it, making it a popular target. The bright galactic nucleus at the centre contains a supermassive black hole estimated to be at least a billion times the mass of our Sun – the closest of its kind to Earth.

JELLYFISH TENDRILS

7 January 2017

The Jellyfish Nebula and its gaseous tentacles are part of the supernova remnant IC 443, the wispy remains of a massive star that blew up in a spectacular death many thousands of years ago. Studies have revealed that this intense explosion left a neutron star behind – a tiny star that has immense mass and gravitational influence. The two bright-yellow stars that sit either side of the cosmic sea jelly are Mu and Eta Geminorum, stars in the constellation of Gemini. Although researchers have discovered the Jellyfish Nebula is 5,000 light years away, they haven't agreed on its age. However, most estimates put the object at around 30,000 years old.

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FOCUS ON

MOONQUAKES COULD ‘SMOOTH OUT’ THE SURFACES OF JUPITER AND SATURN’S ICY MOONS

Tectonic activity triggered by the gravitational influence of the gas giants causes landslides of debris

Reported by Robert Lea

Moonquakes may be smoothing out the surfaces of moons orbiting gas giant planets Jupiter and Saturn, new research has revealed. The findings could solve a long-standing mystery regarding why many of these icy moons have such smooth terrain. Scientists have known for some time that some of the moons that orbit the gas giants Jupiter and Saturn, the largest and second-largest planet in the Solar System respectively, are geologically active. This is the result of the massive gravitational influence of these planets that stretches and squeezes the moons orbiting them, triggering moonquakes that crack the moon’s crusts and icy surfaces. This new research implies these moonquakes can also trigger landslides that help create smooth terrains. The link between moonquakes and landslides indicates how the surfaces of these moons evolve.

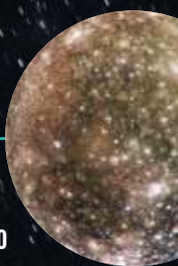
Steep ridges surrounded by relatively smooth areas are a common sight across the landscapes of the Jovian moons Europa and Ganymede, as well as Saturn’s moon Enceladus. While scientists have speculated that these features are the work of liquid flowing from icy volcanoes, quite how the process works at low temperatures on these frigid moons that are inhospitable to liquids, has been a puzzle. The explanation put forward in this new research doesn’t require the presence of liquid on the surface of these icy moons, however. The team came to the surprising conclusion when they set about measuring the dimensions of these ridges, thought to be steep slopes caused by the surface breaking along a fault line

FROZEN WORLDS OF THE SOLAR SYSTEM

The Moon
Protected from the Sun, the deepest, darkest craters at the Moon’s poles are believed to almost certainly contain traces of water ice.

Europa
Europa’s bright, fractured surface is a likely sign of water ice. Scientists believe it has an icy crust of a few kilometres thick, with an ocean underneath.

Ganymede
Ganymede’s ice shell is about 800km (500 miles) thick, according to NASA. The lumpy ice on Ganymede’s surface probably has some rock mixed in too.



Callisto
The ice on Callisto’s surface occasionally twists into 100m (330ft)-tall spires. NASA believes

with one side dropping in what scientists call "tectonic fault scarps". They then applied the measurements to seismic models which allowed them to estimate the power of moonquakes in the history of these moons.

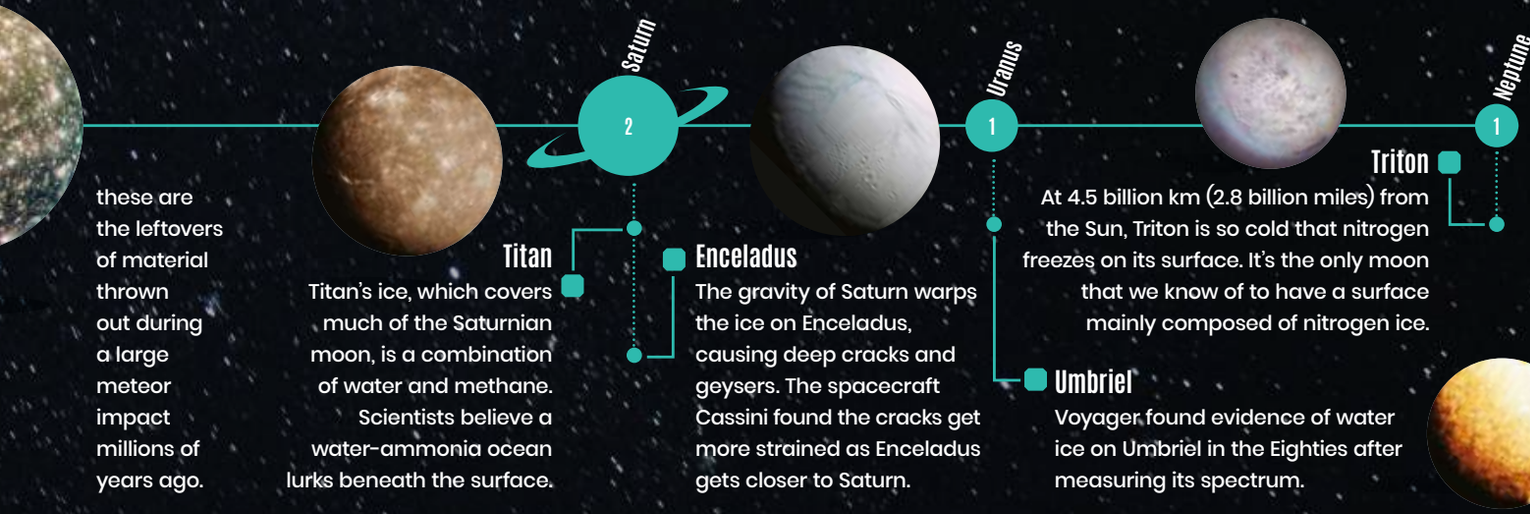
This revedled that some of these seismic events would have been strong enough to hoist up debris that then rolls downhill, spreading out as it does so and smoothing out the landscape of the moons. "We found the surface shaking from moonquakes would be enough to cause surface material to rush downhill in landslides. We've estimated the size of moonquakes and how big the landslides could be," research lead author and University of Arizona in Tucson graduate student Mackenzie Mills, said. "This helps us understand how landslides might be shaping moon surfaces over time."

The research conducted by Mills during a series of summer internships at NASA's Jet Propulsion Laboratory in Southern California will get a major boost when NASA's Europa Clipper mission heads to Europa in 2024. The Europa Clipper mission will orbit Jupiter and conduct about 50 flybys of Europa in the process, collecting images and scientific data with its payload of nine science instruments. This should also help planetary scientists determine if there is a deep liquid ocean beneath the icy shell of the Jovian moon and if it possesses the conditions needed to support life. "It was surprising to find out more about how powerful moonquakes could be and that it could be simple for them to move debris downslope," Europa Clipper project scientist Robert Pappalardo said.

The team said it was particularly surprising to discover the strength of tectonic activity and quakes on Enceladus, as this moon of Saturn has less than three per cent of the surface area of Europa and about 1/650 that of Earth. "Because of that moon's small gravity, quakes on tiny Enceladus could be large enough to fling icy debris right off the surface and into space like a wet dog shaking itself off," Pappalardo said. "We hope to gain a better understanding of the geological processes that have shaped icy moons over time and to what extent their surfaces may still be active today."

Geological processes have shaped icy moons

"Quakes on tiny moon Enceladus could be large enough to fling icy debris off the surface and into space"


Saturn
2
Uranus
1
Neptune
1
these are the leftovers of material thrown out during a large meteor impact millions of years ago.
Titan
Titan's ice, which covers much of the Saturnian moon, is a combination of water and methane. Scientists believe a water-ammonia ocean lurks beneath the surface.
Enceladus
The gravity of Saturn warps the ice on Enceladus, causing deep cracks and geysers. The spacecraft Cassini found the cracks get more strained as Enceladus gets closer to Saturn.
Umbriel
Voyager found evidence of water ice on Umbriel in the Eighties after measuring its spectrum.
Triton
At 4.5 billion km (2.8 billion miles) from the Sun, Triton is so cold that nitrogen freezes on its surface. It's the only moon that we know of to have a surface mainly composed of nitrogen ice.

© Getty Images

SECRET LIVES OF SPACE'S GREATEST HEROES

These six men and women made groundbreaking contributions to our understanding of the universe, and their stories are often linked in surprising ways

Written by Giles Sparrow

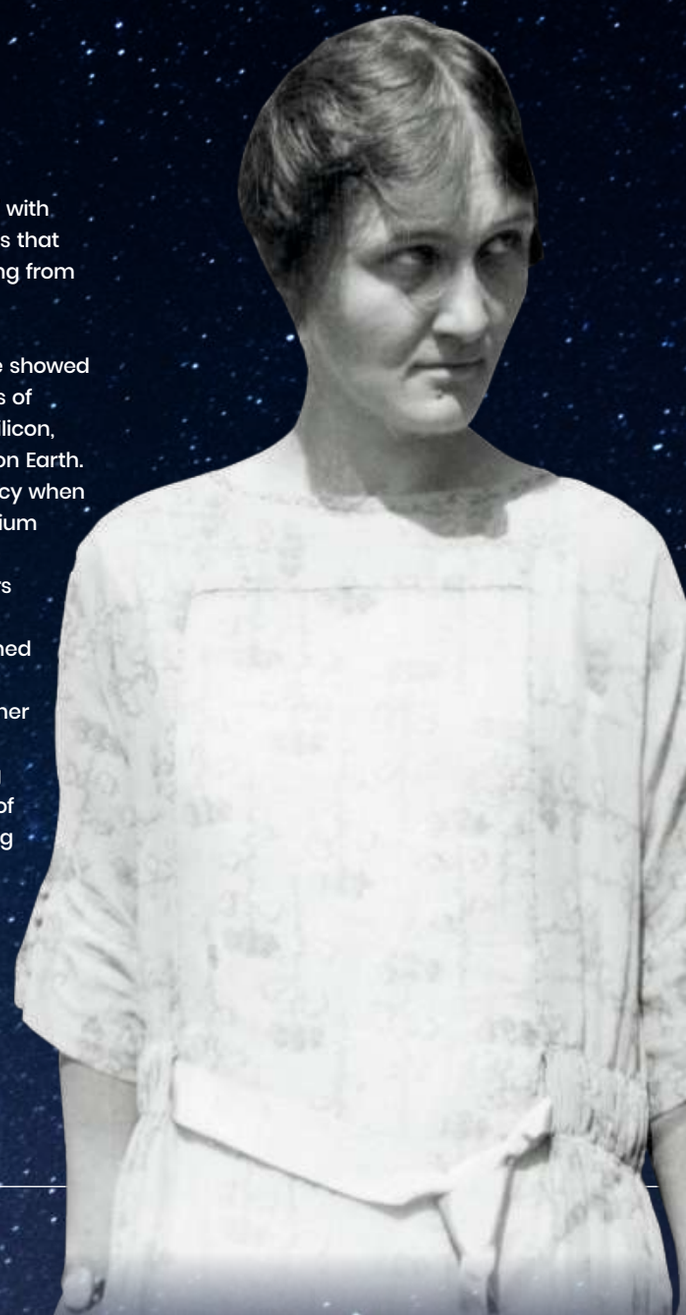
CECILIA PAYNE-GAPOSCHKIN

It was while studying at Newnham College, Cambridge, in 1919 that her interest in astronomy was ignited by a lecture from Sir Arthur Eddington on Einstein's new science of general relativity. Determined to follow her newfound passion after leaving Cambridge, she applied to Harvard College Observatory. Alongside images of the sky, the Observatory's catalogue also included the spectra of countless stars, made by spreading out starlight according to its wavelength and capturing it on photographic plates. These rainbow-like bands were usually crossed by a variety of dark 'absorption lines' – chemical fingerprints created by the light-absorbing properties of various elements somehow associated with the stars themselves. The goal of her PhD thesis would be to explain exactly how.

One of the most puzzling aspects of stellar spectra was the huge variety in the strength and number of their absorption lines, implying great variation in the elements they contained – by proper application of the equation, Cecilia was able to show that most of this variety was due to differences in the surface temperature of the stars, not to their composition. Higher temperatures strip away more of the electrons from around atoms in a star's atmosphere, leaving 'ions' with increasingly positive electric charges that interact differently with light escaping from the star's surface.

Applying these principles to the atmospheres of various stars, Payne showed that they contained similar amounts of relatively heavy elements such as silicon, carbon and oxygen to those found on Earth. But there was a troubling discrepancy when it came to the lightest elements: helium and especially hydrogen seemed to be vastly more abundant in the stars than they are on Earth.

Throughout a long and distinguished career spent entirely at Harvard, Cecilia was able to see the fruits of her breakthrough in understanding the composition of stars. Understanding that they are predominantly made of hydrogen is the key to understanding the fuel source that powers them, the conditions inside them and the various tracks along which they can evolve during their lifetimes.



> Payne anaylsed the spectra of stars and unlocked the secrets of stellar composition

Galileo clashed with the Catholic Church by siding with Copernicus' heliocentric Solar System

GALILEO GALILEI

The great Italian astronomer and physicist Galileo inherited his interest in science from his musical father. Vincenzo Galilei specialised in the lute, a distant relative of modern guitars, and was also a musical theorist who used experimentation and mathematics to identify a new law that correctly described the relationship between the tension on a string and its musical pitch. Vincenzo's discoveries helped to inspire his son's mathematical approach to problems of 'natural philosophy' and foreshadowed Galileo's own struggles to overturn outdated views of the world.

At age 17, Galileo became a student in the University at Pisa, training in medicine at his father's suggestion. He made his first great discovery – that a pendulum has a regular period regardless of the width of its oscillations – while watching a swinging lamp in Pisa Cathedral, and had soon turned it into a practical device for measuring a patient's pulse. After persuading his father to let him pursue his interest in mathematics, he became a professor by the age of 25.

Throughout his life, Galileo was perpetually short of cash. His father's death left him responsible for his mother and three younger siblings – and later his own partner and three children. He boosted his income by taking in private students and selling his inventions, and later took a better paid job at Padua in the Republic of Venice. It was here in 1609 that he got word of an amazing new invention from the Netherlands – the telescope.

Galileo immediately set out to make a telescope of his own, using lenses mounted at either end of a card tube. Thanks to his talents for maths and experimentation, he soon found ways of improving on the basic idea. When he showed it to the Venetian rulers, they offered to double his salary and pay handsomely for the instrument itself.

Within a few months, the course of Galileo's life was fatefully changed as he turned his telescope to the sky and made a series of discoveries including mountains on the Moon, countless faint stars and four small moons circling Jupiter. These findings undermined the traditional view that everything in the universe circled Earth – Nicolaus Copernicus, a Polish priest, had suggested the idea of a Sun-centred universe in 1543, but until now there had been no observational evidence to back it up.

Galileo's account of his discoveries in his book *The Starry Messenger* turned him into a scientific celebrity, but from 1613 onwards his arguments in support of the Copernican model put him on a collision course with the Roman Catholic Church. Powerful connections helped to protect him at first, but an argumentative nature got him into repeated trouble, and his 1632 Dialogue Concerning the Two Chief World Systems led to a trial before the inquisition and a sentence of house arrest for the rest of his life. Nevertheless, he continued to make important contributions to the foundations of modern physics right up until his death in 1642.

GALILEO'S PLANET: JUPITER

Jupiter is the Solar System's largest planet. Its volume is 1,321-times larger than Earth's and its mass is 318-times ours.

It's named after the Roman god Jupiter, the god of sky and thunder.

It's the fourth-brightest object in the sky after the Sun, Moon and Venus.

Jupiter has 53 confirmed moons, its four largest being Io, Europa, Callisto and Ganymede.

The 'King of the Solar System' has faint dusty rings. They weren't discovered until 1979.

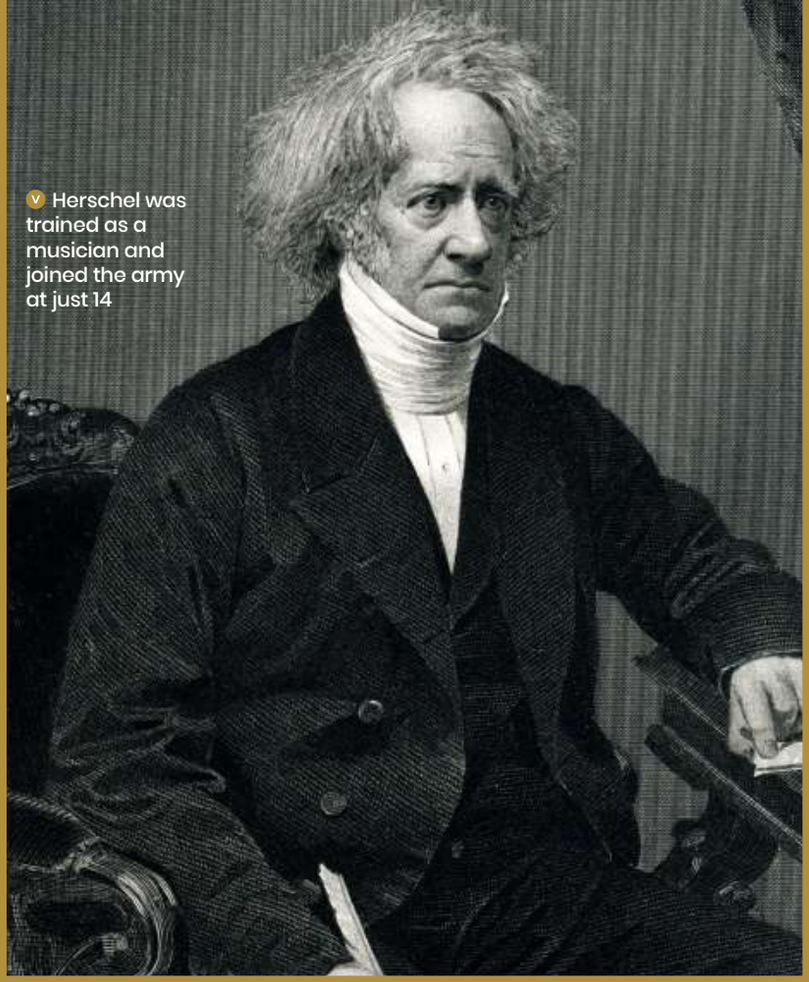
The Great Red Spot on Jupiter is a storm that's large enough to engulf the Earth. It's been swirling for at least 300 years.

It has the fastest rotation in the Solar System, completing a spin in less than ten hours – fast enough to cause a bulge at the equator.

It's difficult to pinpoint when Jupiter was discovered – being visible to the naked eye, records date back to the 7th or 8th century CE.

© DEA / G. Dagli orti / Getty

WILLIAM HERSCHEL



Herschel was trained as a musician and joined the army at just 14

No one knows quite when William became interested in astronomy, but his sister Caroline's memoirs recall him discussing the night sky with her on their journey to England. Shortly after their arrival, he began building his own telescopes – at first simply by assembling lenses obtained by local glassmakers, but later, as his needs grew more demanding, by casting mirrors and building reflecting telescopes of his own design.

Eventually, William had instruments that were fit for his plans – not just to observe the night sky, but to carry out detailed surveys in search of comets and other undiscovered objects. His telescopes were the best of their age, and his reputation soon began to spread. His first project involved a systematic catalogue of closely spaced stars, with William spending all his available nights at the eyepiece and Caroline making careful notes. At the time most people assumed that stars were randomly scattered through space, but the discovery of numerous close pairs convinced him otherwise. There were too many to be accounted for by chance alignments, so some of them at least must be paired binary stars in orbit around each other.

In March 1781, William spotted the planet now called Uranus. When he first saw the spherical bluish blob in the constellation of Taurus, he assumed it was a comet – it was Astronomer Royal Nevil Maskelyne who began to wonder whether the unusually solid-looking object might be a planet beyond Saturn. A few months later, continued tracking of the object's movement confirmed that it was indeed a remote planet. Herschel suggested naming it George's Star – after King George III – and the king returned the honour by naming William his personal astronomer and granting him a salary of £200 on condition that he moved to Windsor, with an additional £50 for Caroline to work as his assistant. The Herschels, both brother and sister, abandoned their musical careers to become some of Europe's first professional scientists. They would go on to make countless other discoveries.

"His first project involved a systematic catalogue of closely spaced stars"

INSIDE URANUS

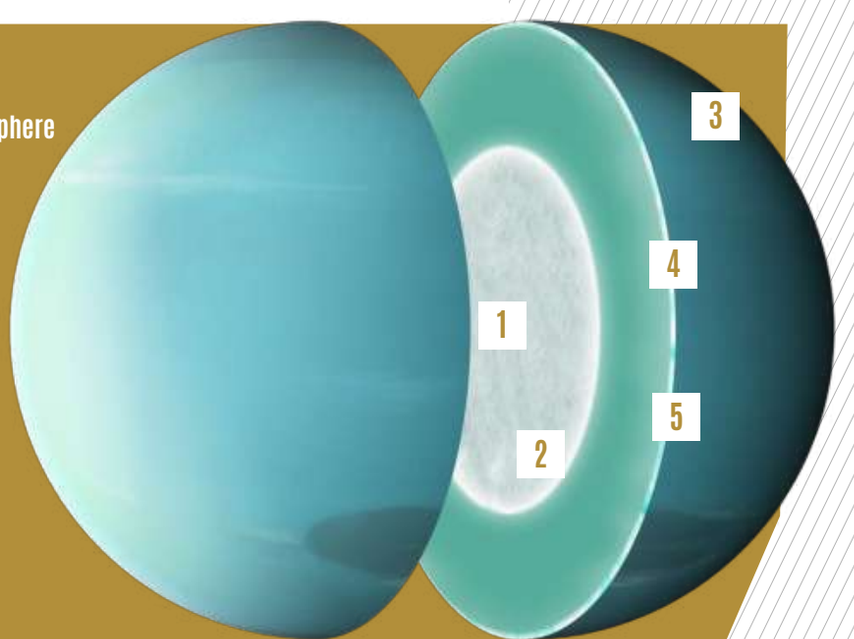
1 Planetary core
Uranus' 5,000°C (9,032°F) core extends to about a fifth of the planet's diameter, and is made of rock, ice and silica.

2 Icy mantle
This isn't ice as we know it. Uranus' mantle is made up of a hot, dense fluid scientists refer to as a water-ammonia ocean.

3 Upper atmosphere haze
The highest parts of Uranus' atmosphere are thought to contain haze made up of hydrocarbons that obscures features lower in the atmosphere.

4 Potential heat-trapping layer
A layer around Uranus' ice layer trapping heat could have formed during a giant impact.

5 Atmosphere
It looks bluish-green due to methane. It also has hydrogen, helium, acetylene and other hydrocarbons.



HENRIETTA SWAN LEAVITT

Several remarkable female astronomers played a key role in establishing our understanding of the stars in the late-19th and early 20th centuries, and Henrietta Swan Leavitt was arguably the most important of them all, laying the foundations for a revolution in our view of the entire universe.

Leavitt was born in 1868 to a well-off Massachusetts family. After displaying an early academic talent, she studied at Oberlin College in Ohio and Harvard University's Society for the Collegiate Instruction of Women (later Radcliffe College). Although she showed a talent for mathematics, she did not take a course in astronomy until her fourth year of university.

After graduating in 1892 – without a degree since at the time they were not awarded to women – Henrietta pursued her newfound interest in the heavens by applying to work at Harvard College Observatory. Here, astronomer Edward Charles Pickering was assembling a team of women to catalogue and analyse data being gathered by the first photographic survey of the sky. Work was often published under Pickering's name with little acknowledgement of the women behind the scenes. Nevertheless, the so-called 'Harvard Computers' would make huge contributions to our understanding of the structure and evolution of stars.

Henrietta's particular speciality was the analysis of variable stars – measuring how their brightness fluctuated between photographic plates taken on different nights and trying to identify patterns. However, her career was somewhat intermittent, with frequent breaks for travel, family responsibilities and for the good of her delicate health and overstrained eyesight.

It was in 1904 that she turned her attention to new plates sent from the observatory's Southern Hemisphere outpost at Arequipa in Peru. These images showed the Small Magellanic Cloud (SMC) – a crowded clump of stars near the southern Milky Way. Here, Leavitt found and analysed more than 1,770 new variable stars. Among them, she spotted 16 with a distinctive cycle of changing light that suggested they were related.

In a 1908 paper reporting her discoveries, she noted that among these stars, the brighter ones had longer periods. Because stars in the cloud could be assumed to lie at the same distance from Earth, their apparent brightness in photographs would be a reflection of their true physical brightness, or 'luminosity', something that wasn't true for stars randomly scattered elsewhere in the sky.

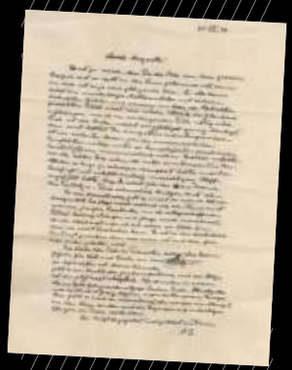
After identifying several more stars to conclusively prove the link, Henrietta published her 'period-luminosity relationship' in a paper of 1912. The implications were huge: astronomers soon realised that Henrietta's stars were of a familiar type known as Cepheids, and this meant that the relative distances of similar stars elsewhere in the sky could be worked out.

Henrietta succumbed to stomach cancer in 1921, before the full implications of her work became clear. Just four years later, Edwin Hubble found and measured Cepheid variables embedded in some of the mysterious 'spiral nebulae' that dotted the sky. He showed that they were fainter even than those in the SMC, and conclusively proved that the nebulae are actually galaxies far beyond the Milky Way. Today, Cepheids remain a vital rung on the cosmic-distance ladder used to measure the scale of the universe.

Henrietta died in 1921, before the full implications of her work became clear

She specialised in the analysis of variable stars

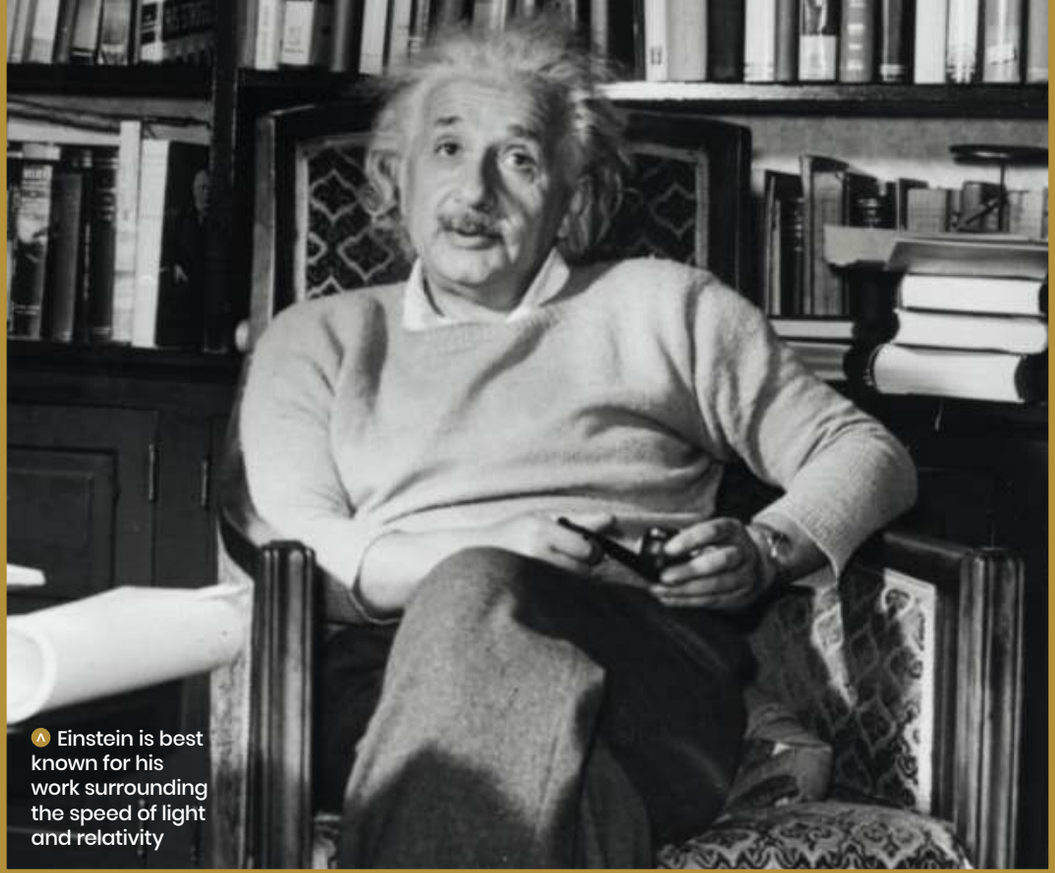
A letter sent to U.S. President Franklin D. Roosevelt, signed by Albert Einstein, details uranium as a new and important source of energy in the "immediate future"



Albert Einstein pens a romantic letter to Russian spy Margarita Konenkova

This signed letter dates back to 1928 and concerns the formalisation of the 'Third Stage of the Theory of Relativity'

A letter signed by Albert Einstein to Ernst Gabor Strauss about the unified field theory



Einstein is best known for his work surrounding the speed of light and relativity

ALBERT EINSTEIN

Born in Ulm, southern Germany, in 1879, Albert Einstein would become the most famous physicist of the 20th century, introducing revolutionary ideas that transformed all of science – and astronomy in particular.

After graduating from the Federal Polytechnic School in Zürich, he found employment at the Bern patent office, in a job that left him with plenty of spare time to work on his PhD and consider the questions that he was really interested in.

In 1905, he stepped into the limelight with the publication of not one, but four groundbreaking scientific papers. One provided long-sought-after direct proof of the existence of atoms. Another laid the foundations for what would become known as quantum physics, but it was the other two that transformed our view of the universe itself.

Einstein's breakthrough came from confronting questions about the speed of light, which always seemed to be the same regardless of the relative motions of the light source and the measuring device. Physicists had put forward many possible explanations for this troubling phenomenon, but all relied on it being a kind of illusion, and none of them were satisfactory.

Einstein, however, dared to ask if the speed of light really is constant, regardless of relative motion. He showed that the consequences for everyday life would be unnoticeable, but that in 'relativistic' situations, with an observer and an object or light source moving at near-light speed relative to each other, strange effects would occur. From the observer's point of view, objects at near light speed appear to become shorter and to experience time more slowly.

Further consideration led Einstein to conclude that accelerating objects already at relativistic speeds will tend to increase their mass rather than their speed – since the speed of light itself is unreachable – and this led in turn to the famous equation $E=mc^2$.

Einstein's ideas were hugely influential, but Albert himself was already pondering the next big question. So far he had only formulated a 'special theory of relativity' where the observer and object moved at high relative speed, but did not accelerate or decelerate. He now realised that acceleration was effectively the same as being in a gravitational field, so a description of 'general relativity' would also automatically be a description of gravity itself.

Einstein's theory of general relativity, when it emerged, showed that the presence of large masses can have effects similar to those seen in special relativity, distorting our measurements of time and space. However, its publication in 1916, as Europe tore itself apart in WWI, meant it was widely overlooked.

It was only in 1919, following the return of peace, that astronomer Sir Arthur Eddington was able to journey to Africa and make crucial observations of stars around the Sun during a solar eclipse. These revealed the effect we now call gravitational lensing in the form of a slight distortion in the measured positions of the stars as light is deflected due to the Sun's distortion of nearby space and time. Einstein was proved right, opening the way for a new era in physics, and eventually for new astronomical techniques that make use of his discoveries and predictions.

KATHERINE JOHNSON

Katherine grew up in the southern United States at a time when racial segregation was commonplace and opportunities for African Americans were in short supply. In 1952, Katherine learned that the National Advisory Committee for Aeronautics (NACA) was looking to hire mathematicians. At first she was assigned to the group of black women 'computers' who did the number-crunching to analyse data gathered from NACA's research aircraft. Her particular talent was soon recognised, however, with a temporary posting within an all-male, all-white team at the Flight Research Division that became permanent.

After the surprise launch of the Soviet Union's Sputnik satellite in 1957, chaotic early US attempts to play 'catch up' culminated in a wholesale reorganisation of NACA to form the nucleus of the current NASA. Racial and gender segregation were done away with, while the Flight Research Division was renamed the Space Task Group and was charged with putting American astronauts into orbit ahead of the Soviets. As well as working on Alan Shepard's Freedom 7 suborbital flight in 1961, Katherine co-authored work on the precise placement of satellites in particular orbits and the relationship between a spacecraft's re-entry point and its landing site.

Despite machine-based calculation fast becoming the norm at NASA, the early 'Mercury 7' astronauts were reluctant to put their lives entirely in the hands of technology, and John Glenn famously asked for Katherine to manually recheck the calculations before the launch of his Friendship 7 spacecraft on the first US orbital mission.

Johnson continued to work at NASA until her retirement in 1986. She considered her proudest achievement to be the calculations needed to sync the Apollo Lunar Module with the orbiting Command Module. She also helped devise a method of 'navigation by the stars' that allowed the astronauts of the crippled Apollo 13 spacecraft to time the precise engine burn needed to return them to Earth. In 2015, she was awarded the Presidential Medal of Freedom.

74
Memory (ROM) of the Apollo guidance computer, in kilobytes

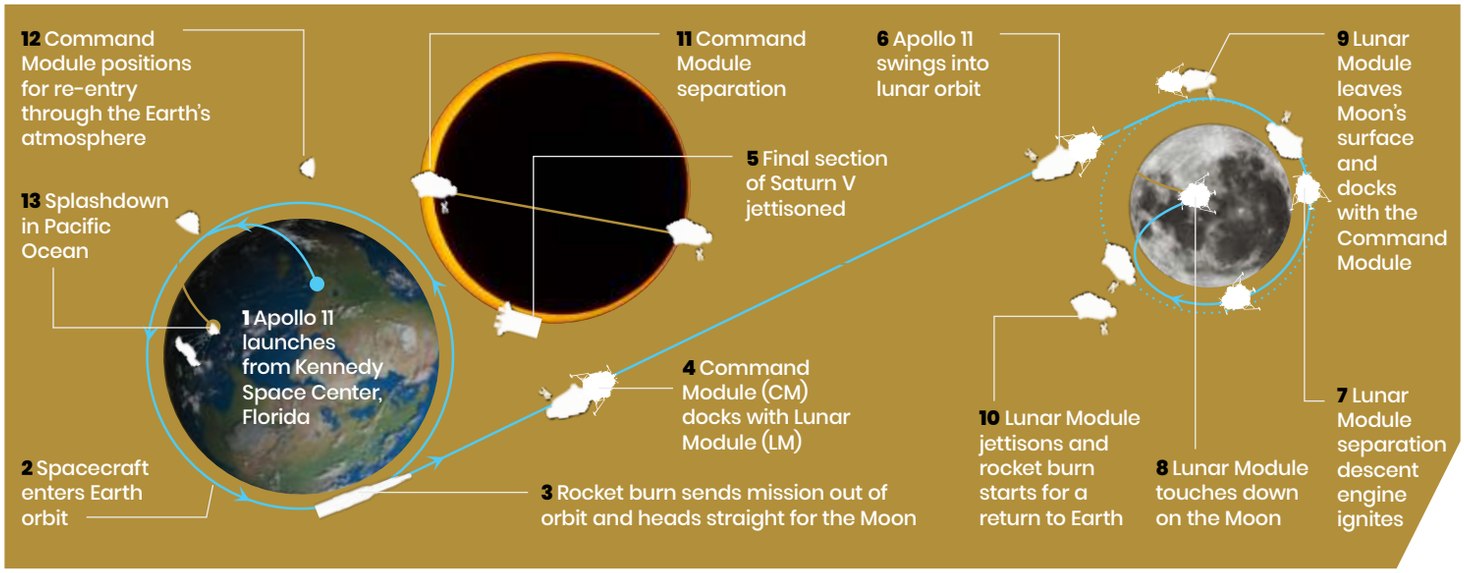
1202
The first of several 1202 and 1201 computer alarms began to sound when Armstrong ignited the descent engine on the lunar lander

9
Early versions of the Sony Walkman portable cassette recorders were flown on the Apollo missions

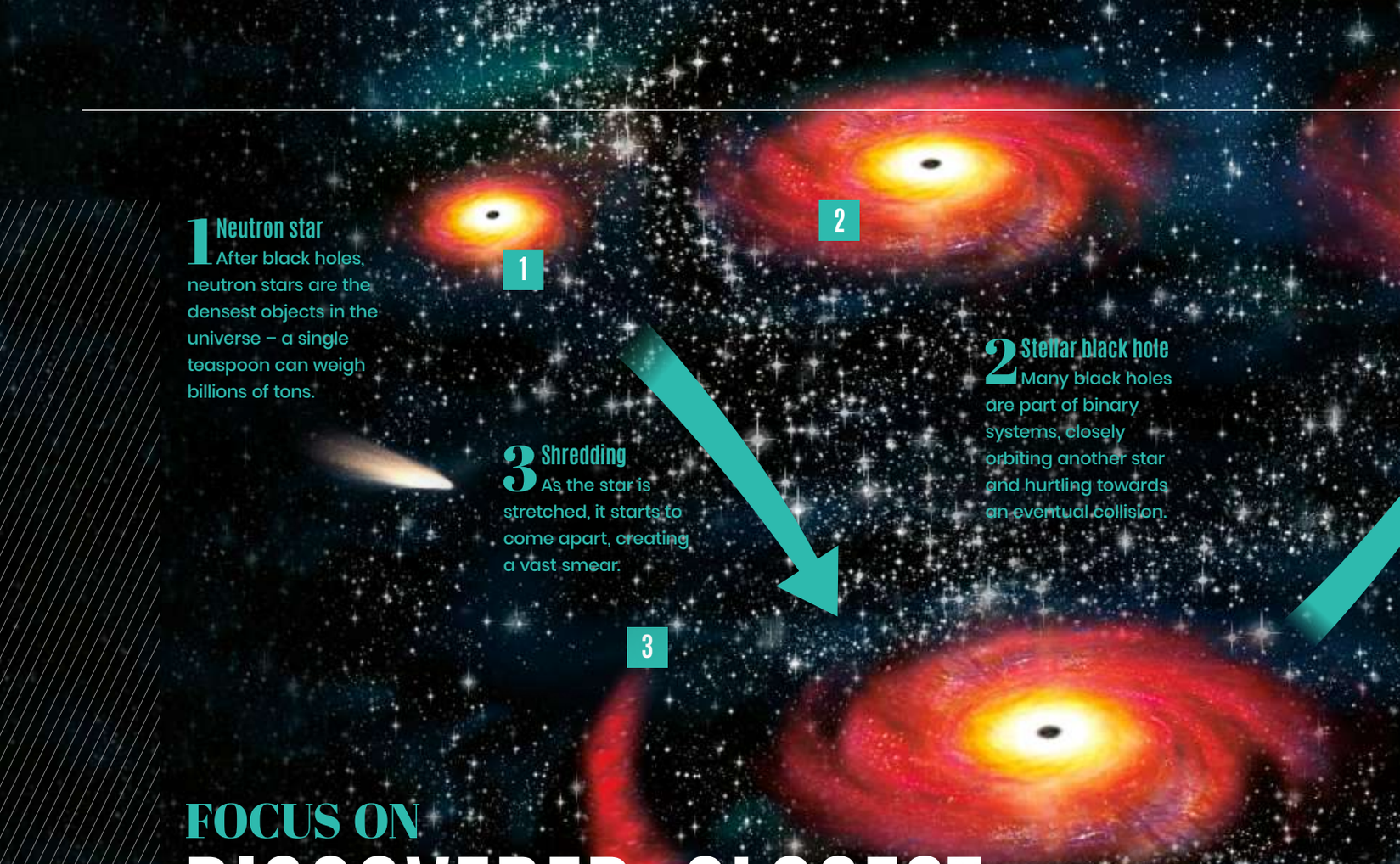
6.7
The diameter of the Saturn V computer in metres

36
Weight of satellites launched by Apollo in kilograms

Johnson played a key role in NASA's space programme


12 Command Module positions for re-entry through the Earth's atmosphere
13 Splashdown in Pacific Ocean
1 Apollo 11 launches from Kennedy Space Center, Florida
2 Spacecraft enters Earth orbit
3 Rocket burn sends mission out of orbit and heads straight for the Moon
4 Command Module (CM) docks with Lunar Module (LM)
5 Final section of Saturn V jettisoned
11 Command Module separation
6 Apollo 11 swings into lunar orbit
9 Lunar Module leaves Moon's surface and docks with the Command Module
10 Lunar Module jettisons and rocket burn starts for a return to Earth
8 Lunar Module touches down on the Moon
7 Lunar Module separation descent engine ignites

Source: Wikipedia NASA; Getty Images



1 Neutron star
After black holes, neutron stars are the densest objects in the universe – a single teaspoon can weigh billions of tons.

2 Stellar black hole
Many black holes are part of binary systems, closely orbiting another star and hurtling towards an eventual collision.

3 Shredding
As the star is stretched, it starts to come apart, creating a vast smear.

4 Spaghettification
The front edge of the star is closer to the centre of the black hole, and the gravitational pull is stronger, stretching it out into a wide arc as it spirals inwards.

FOCUS ON

DISCOVERED: CLOSEST STAR-SHREDDING BLACK HOLE TO EARTH EVER SEEN

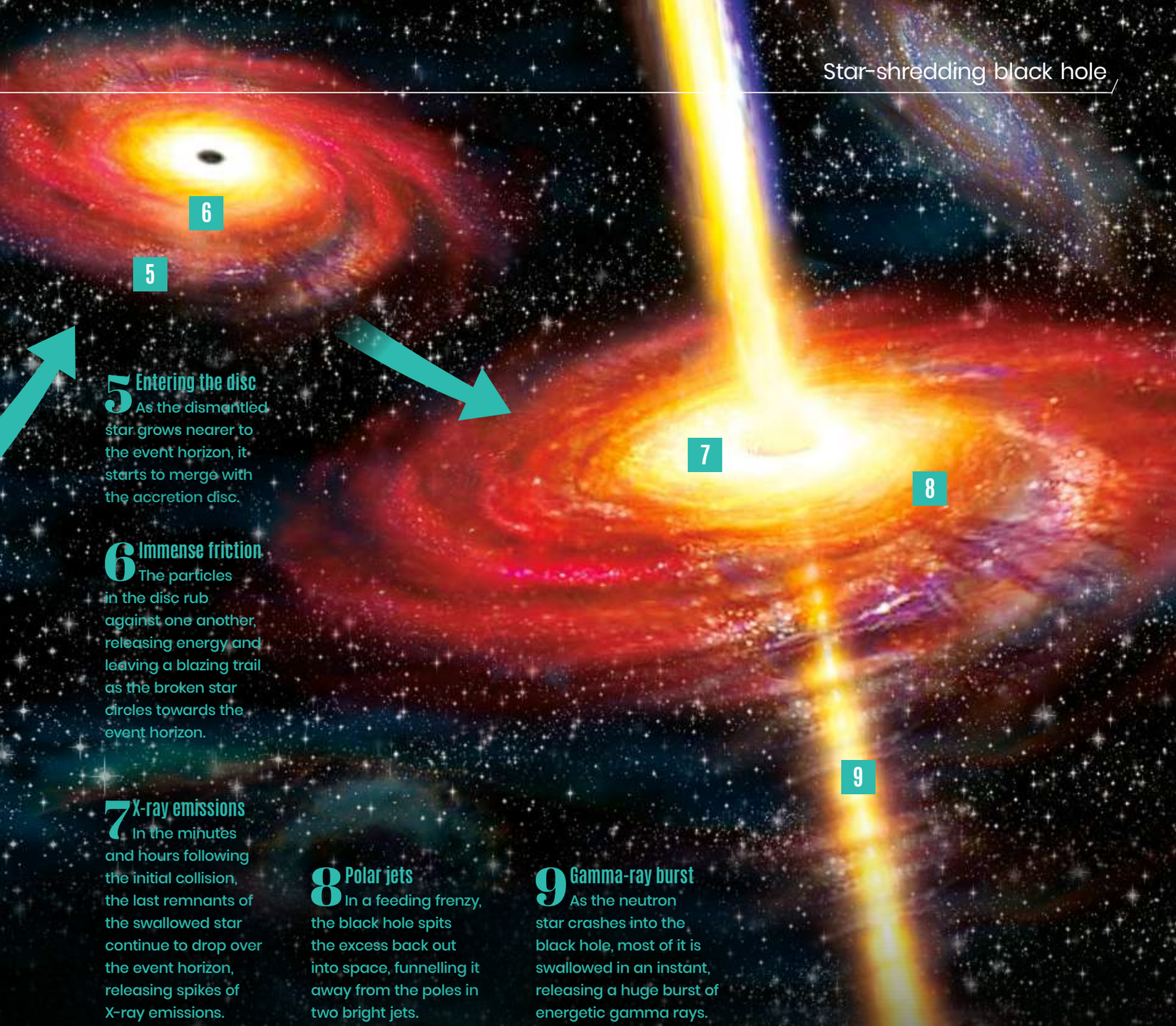
It was found by astronomers comparing maps of the universe

Reported by Briley Lewis

A long time ago in a galaxy not so far away, a supermassive black hole ripped a star to shreds in the centre of the galaxy NGC 7392. The flash of light from the black hole's dinner finally reached Earth in 2014 – and astronomers have just discovered it in their data.

This newly detected outburst from the centre of NGC 7392 is the closest-yet example of a tidal disruption event (TDE), where a star is pulled apart by the massive gravitational pull of a black hole.

The hungry black hole was spotted roughly 137 million light-years from Earth – or about 35 million times as far as Proxima Centauri, the closest star to the Sun. As distant as that sounds, astronomers have only observed around 100 of these events so far, and this one is four times closer than the previous title holder of "closest TDE to Earth." Scientists discovered the TDE in infrared, a different wavelength than most conventional TDE detections, which usually come in X-rays, ultraviolet and optical light. "Finding this nearby TDE means that statistically, there must be a large population of these events that traditional methods were blind to," said Christos Panagiotou, an astronomer at the Massachusetts Institute of Technology. "So we should try to find these in infrared if we want a complete picture of black holes and their host galaxies."



5 Entering the disc
As the dismantled star grows nearer to the event horizon, it starts to merge with the accretion disc.

6 Immense friction
The particles in the disc rub against one another, releasing energy and leaving a blazing trail as the broken star circles towards the event horizon.

7 X-ray emissions
In the minutes and hours following the initial collision, the last remnants of the swallowed star continue to drop over the event horizon, releasing spikes of X-ray emissions.

8 Polar jets
In a feeding frenzy, the black hole spits the excess back out into space, funnelling it away from the poles in two bright jets.

9 Gamma-ray burst
As the neutron star crashes into the black hole, most of it is swallowed in an instant, releasing a huge burst of energetic gamma rays.

After first spotting the TDE in observations from the NEOWISE space telescope, Panagiotou and collaborators sifted through data from many other observatories and space telescopes to dig up more information on NGC 7392's supermassive black hole. They wanted to solve the mystery of why this TDE only appeared in infrared, instead of more energetic wavelengths like others of its kind. Previously discovered TDEs mostly appeared in so-called green galaxies, which don't create as many stars as the more active blue galaxies, but aren't totally burned out on star-making like red galaxies. NGC 7392, however, is a blue galaxy – churning out many new stars and creating a lot of dust in the process. This dust could obscure the centre of the galaxy, where the supermassive black hole lives, in optical and ultraviolet light. But infrared light enables astronomers to peer through that dust and see what's going on.

This finding suggests that astronomers should be searching for TDEs in infrared light, too. "Using infrared surveys to catch the dust echo of obscured TDEs has already shown us that there is a population of TDEs in dusty, star-forming galaxies that we have been missing," Suvi Gezari, an astronomer at the Space Telescope Science Institute who was not involved in the study, said. By looking for TDEs in infrared too, scientists could get one step closer to understanding how black holes chow down on stars.

"There must be a large population of these events that traditional methods were blind to"
Christos Panagiotou

© Adrian Chesterman

HUNTING FOR INTERSTELLAR PLANETS

Space is suspected to be filled with worlds wandering alone without a star, but could such loners ever shelter life?

Reported by Giles Sparrow

In the past few decades, we've grown used to the idea of exoplanets – distant worlds orbiting stars in alien solar systems. Some of these planets are very different from our own – scorched gas giants skimming the surfaces of their stars or frozen balls of ice larger than Earth. But perhaps the strangest exoplanets are those that drift alone through the darkness of interstellar space, far from the heat and light of any star. Only a handful of these objects are known, but many billions of them could be scattered across our galaxy – estimates vary from at least a couple for each of the Milky Way's 200-billion-plus stars, up to an astonishing 100,000.

Astronomers call these mysterious worlds interstellar or 'rogue' planets, but in order to understand them, we first need to find them and learn more about their characteristics – and that's a challenge in itself. The vast majority of exoplanets discovered so far have been detected through their influence on their parent stars – either the tug of their gravity on the star's path through space or slight dips in the star's brightness as a planet transits in front of its star as seen from Earth. But for interstellar planets, neither of these techniques work. The other obvious route of observing them through their own light and other radiation is also caught in a catch-22 situation: while the light of exoplanets is often drowned by that of the stars they orbit, most are only visible at all thanks to reflected starlight. Earth-like interstellar planets – relatively tiny balls of rock floating far from any stars – are so small, cold and faint as to be almost impossible to detect. The only exception might be if they wander by chance in front of a more distant star and create a microlensing event, where the starlight is bent.

Fortunately, there are occasional lone planets, still hot from the gravitational collapse in which they formed, that give out light of their own, shining dimly but distinctly if viewed through powerful telescopes and emitting radiation that can reveal important clues to their other properties. One intriguing example, catalogued as PSO J318.5-22, was discovered in 2013 by a team including Dr Niall Deacon, now at the Max Planck Institute for Astronomy. Deacon specialises in studying

wide-orbit planets. But it was during a search for brown dwarfs that he and his colleagues stumbled across the object he calls PSO J318.

"We were doing a large survey with the Pan-STARRS [Panoramic Survey Telescope and Rapid Response System] observatory on Maui, Hawaii. We looked for very red objects that drift across the sky a bit – lots of distant galaxies are red, but if an object is moving quickly across the sky, it must be nearby. We detected a bunch of candidates and did follow-up measurements with the United Kingdom InfraRed Telescope on Mauna Kea, and Mike Liu noticed that this object was really, really red. We followed it up with a spectrum from NASA's Infrared Telescope Facility and found that its light was very similar to that of the planets around HR 8799. Based on its colours and spectrum, we knew that it might be a free-floating planet."

But how do you tell the difference between a planet and a brown dwarf? "Brown dwarfs are basically failed stars," explains Deacon. "They're objects that don't have enough mass to push down on their cores and give them high enough temperatures to fuse hydrogen in the middle. The official definition is that brown dwarfs can fuse a small amount of deuterium in their core early in their lifetime."

Brown dwarfs have masses between about 13 and 80 times that of Jupiter, but it leaves the definition of planets rather fuzzy, as Deacon points out: "That definition means that a brown dwarf could form in the disc around a star, rather like a planet forms. But equally, some objects with a mass smaller than the planet-brown dwarf boundary could, in theory, form on their own in a star-like way. You can look at something like Earth or Jupiter and say that's definitely a planet and look at something with about 50 Jupiter masses and say it's definitely a brown dwarf, but what about for something that's about 12 Jupiters? It's a bit iffy how you make that decision." Even working out the mass of an object floating on its own through space might seem like an impossible challenge. What's more, without large amounts of radiation from nuclear fusion to hold them up, large gas planets and brown dwarfs all collapse under gravity into objects of about the same size. So how can you even begin to tell them apart?

The first step, as Deacon explains, is to work out the object's temperature based on features of its spectrum, including its colour. "Because brown dwarfs have no core fusion, they lose heat as they age. But more massive things have more gravitational energy when they collapse, and that turns into more heat that takes longer to radiate away. PSO J318 has a surface temperature of about 1,200 Kelvin [925 degrees Celsius or 1,697 degrees

Pan-STARRS has a wide-field telescope and giant digital camera that make it ideal for surveying large areas of sky

ARE ROGUE PLANETS IDEAL FOR LIFE?

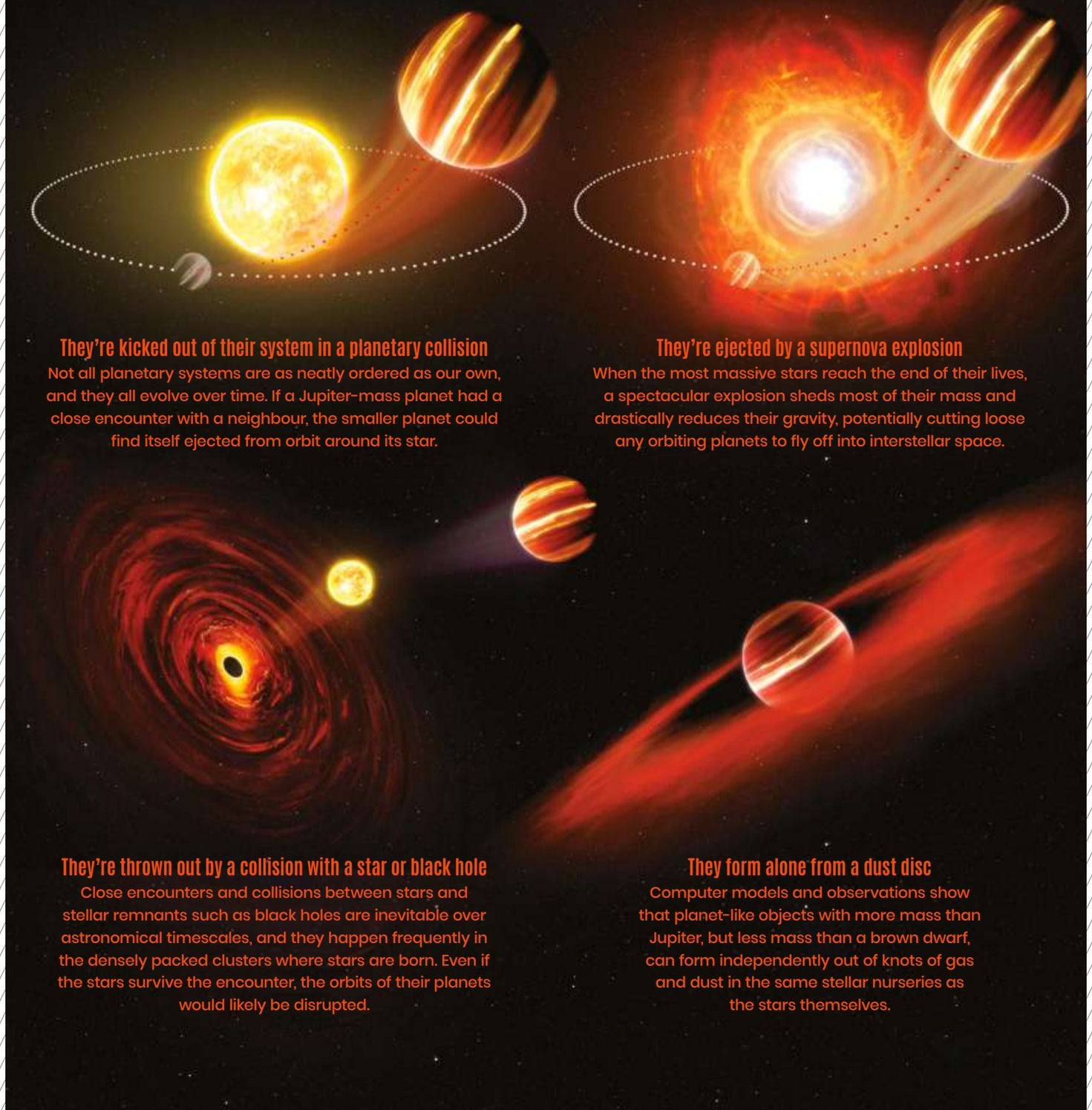
Pretty much all life on Earth is dependent on the Sun to survive, so it might seem strange to imagine life thriving on planets lost in the interstellar darkness. But researchers say we shouldn't write off rogue planets entirely. As early as 1999, David J. Stevenson of the California Institute of Technology argued that even small rogue planets that had been expelled from their solar systems could sustain a hydrogen-rich atmosphere and a warm surface for long enough for life to evolve, thanks to the radiation of energy left over from its formation. This idea is clearly confirmed by the discovery of gas giants like PSO J318, which pumps out enough energy to vaporise iron.

Of course, any life that evolved in the hot atmosphere of a rogue gas giant would be very different from what we see on Earth – conditions might prevent life from gaining a foothold at all, and would almost certainly stop it at the level of bacteria-like organisms that could float among the clouds. But more solid Earth-like worlds with geological activity driven by escaping heat could also have the potential to sustain life on or beneath their surfaces – perhaps similar to the bacteria associated with 'hot rocks' and subterranean water channels on Earth. With photosynthesis out of the question due to a lack of sunlight, the 'primary producers' at the base of any alien food chain would have to find another chemical means of generating energy, perhaps by consuming carbon from the rock itself.

Perhaps the most promising home for life in interstellar space, however, would not be on a rogue planet itself, but on its moons. Here, tidal forces might create an environment similar to those seen on several moons in our own Solar System, with a deep ocean of liquid water heated from below by volcanic activity and shielded from space by a solid icy crust. Such an interstellar ocean could offer hospitable conditions for the development of fairly advanced aquatic life forms.

HOW ROGUE WORLDS ARE MADE

Astronomers have put forward a variety of theories to explain how planets could end up drifting through interstellar space



They're kicked out of their system in a planetary collision

Not all planetary systems are as neatly ordered as our own, and they all evolve over time. If a Jupiter-mass planet had a close encounter with a neighbour, the smaller planet could find itself ejected from orbit around its star.

They're ejected by a supernova explosion

When the most massive stars reach the end of their lives, a spectacular explosion sheds most of their mass and drastically reduces their gravity, potentially cutting loose any orbiting planets to fly off into interstellar space.

They're thrown out by a collision with a star or black hole

Close encounters and collisions between stars and stellar remnants such as black holes are inevitable over astronomical timescales, and they happen frequently in the densely packed clusters where stars are born. Even if the stars survive the encounter, the orbits of their planets would likely be disrupted.

They form alone from a dust disc

Computer models and observations show that planet-like objects with more mass than Jupiter, but less mass than a brown dwarf, can form independently out of knots of gas and dust in the same stellar nurseries as the stars themselves.

Fahrenheit], and for a given temperature there's a link between mass and age. You have to distinguish between something that's high mass and old or low mass and young."

Once you have that temperature information, there are other clues in the star's light that reveal more about its properties. "There are features in the spectrum that tell you how strong the atmospheric gravity is. These are dark absorption lines formed by alkali metals and iron hydride that are pressure sensitive. In higher density atmospheres that are more compressed by gravity, the lines are stronger. And because these objects are all about the same radius, the gravity measurement more or less tells you the mass. If two objects have the same temperature, then a younger less massive one will tend to have weaker spectral lines than an older more massive one," explains Deacon. The weak lines in PSO J318's spectrum pointed towards it being a recently formed interstellar planet with relatively low gravity rather than an older brown dwarf.

But to really get an idea of its properties, the team would need to pin down its age more precisely. They achieved this through some ingenious cosmic genealogy – by tracking down the planet's siblings in space. "PSO J318's distance of 80 light years, its sky position and its motion are linked to a group of young stars called the Beta Pictoris association, and because these stars have an estimated age of about 25 million years, we can assume that PSO J318 is the same age. From that, we were able to work out the mass more accurately and confirm that the object is below 12 Jupiter masses. By the official definition, it's a planet," says Deacon.

So where exactly do rogue planets come from? Some, particularly smaller Earth-like objects, are thought to be celestial runaways that probably began by coalescing like 'normal' planets from the dust and gas in orbit around newly formed stars, but were later ejected from their solar systems by close encounters with planetary neighbours or near misses with other stars. But many others are probably lifelong loners – worlds that coalesced directly from interstellar nebulae in the same way as stars and brown dwarfs. Astronomers believe there is a lower limit to the mass of objects that can form in this way, meaning that even the smallest would have two or three times the mass of Jupiter.

But is there a way to distinguish between the two possible origins of interstellar giants? "There are some suggestions," says Deacon. "An object forming in a disc is going to be affected by the way that ices of different materials condense at different distances from the primary star, and that might cause slight differences in chemical composition from an object that formed in a star-like way, but the idea of detecting those differences is still in its infancy."

For astronomers, interstellar planets have one big advantage over their exoplanet cousins in other solar systems. "When you look at planets orbiting other stars, unless they're in very wide orbits we have to somehow get rid of the light from the primary star," observes Deacon. "We can either do that from space, blocking the light with a device called a coronagraph, or we can use computerised 'adaptive optics' techniques on Earth to correct for the blurring of the atmosphere, sharpen the image of the star and reduce its size. But those are really time-consuming processes, and you can only really do them on the biggest hardest-to-access telescopes."

In contrast, rogue worlds present fewer of these problems. "Almost all the data in our discovery paper came from four-metre (13.1-foot) telescopes or smaller – some of which were over 35 years old," comments Deacon. "If you want to study atmospheres in more detail, or maybe collect time-series data from repeated

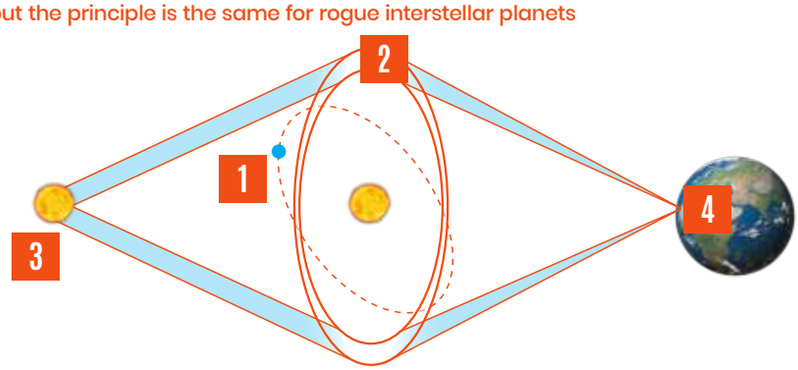
HOW TO FIND A ROGUE PLANET

Gravitational microlensing

Microlensing is a distortion and magnification of a star's light that happens when another object passes in front of it and bends the paths of light passing near it through gravity. It's been used to find exoplanets orbiting other stars, but can also be used to detect interstellar planets, allowing astronomers to estimate how common they are. Microlensing events by interstellar planets tend to be a one-off, so it's hard to learn much about the planets themselves.

Microlensing at work

This shows how microlensing reveals exoplanets in orbit around stars, but the principle is the same for rogue interstellar planets



1 Orbiting planet
A star closer to Earth is orbited by an unseen planet.

2 Distorted light
As the distant star's light passes close to the planet, it's deflected, with some bent towards Earth.

3 Distant starlight
Light from a distant star spreads out on straight-line paths in all directions.

4 Magnified image
Astronomers on Earth see the starlight distort and brighten in a characteristic way, revealing the mass of the intervening object.

Direct imaging

The direct detection of interstellar planets relies on long-exposure surveys of large areas of the sky looking for brown dwarfs and other faint objects. Infrared surveys are particularly useful since many of these objects emit more radiation as heat than they do as light. Surveys often target areas of recent star formation where objects are likely to be at their youngest, and therefore hottest and brightest.

WANDERING WORLDS WE'VE FOUND SO FAR

Cha 110913-773444

Distance: 529 light years
Discovery method: Direct observation
Constellation: Chamaeleon

Discovered in 2004, Cha 110913-773444 has the mass of about eight Jupiters, making it a interstellar planet candidate. Infrared observations show that it is surrounded by a faint disc of planet-forming material, perhaps moons in formation?

WISE 0855-0714

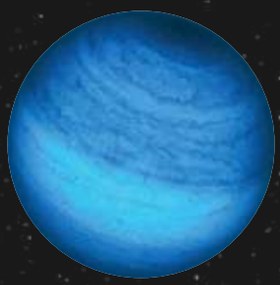
Distance: 7.4 light years
Discovery method: Direct observation
Constellation: Hydra

Discovered in 2014, this small object is a little over seven light years away. With a surface temperature of -30 degrees Celsius (-22 degrees Fahrenheit), it's either a cold, low-mass brown dwarf or an interstellar planet on our cosmic doorstep.

PSO J318.5-22

Distance: 80 light years
Discovery method: Direct observation
Constellation: Capricornus

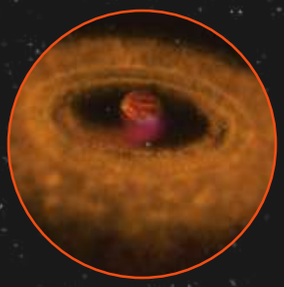
PSO J318 is the best studied rogue planet so far, with a tightly constrained mass and age that indicate it's undoubtedly a planet rather than a brown dwarf. It was discovered in 2013.



CFBDSIR 2149-0403

Distance: 130 light years
Discovery method: Direct observation
Constellation: Aquarius

CFBDSIR 2149-0403 seems to be part of the AB Doradus moving group, a group of stars that are 50 to 120 million years old. With a surface temperature of 430 degrees Celsius (806 degrees Fahrenheit), its mass is likely between four and seven Jupiters.



OTS 44

Distance: 554 light years
Discovery method: Direct observation
Constellation: Chamaeleon

This faint young object has a mass between 6 and 17 Jupiters, putting it on the boundary between brown dwarf and planet. Excessive infrared radiation from its surroundings suggests it is shrouded by a disc of planet-forming material.

observations over hours or days on end to look for trends, you can do that much more easily using a smaller and more accessible telescope if the planet's sitting on its own."

In 2015, a team led by Dr Beth Biller at the University of Edinburgh did just this with PSO J318, carrying out precision measurements of the planet's light and identifying slight variations in the planet's brightness as it rotates and displays different hemispheres to Earth. They found that it rotates in a little over five hours and has a blotchy surface best understood as patchy regions of cloud. Similar cloud features have previously been detected on brown dwarf stars, but those on PSO J318 seem to be thicker. "They could be clouds of silicate dust," says Deacon, "or perhaps condensing molten iron, since at these temperatures they could have iron vapour in their atmosphere. On a planet like this you could have molten-iron rain!"

It's bizarre to imagine that a planet exiled from its parent star – if it ever had one – and drifting alone through the dark and icy depths of interstellar space

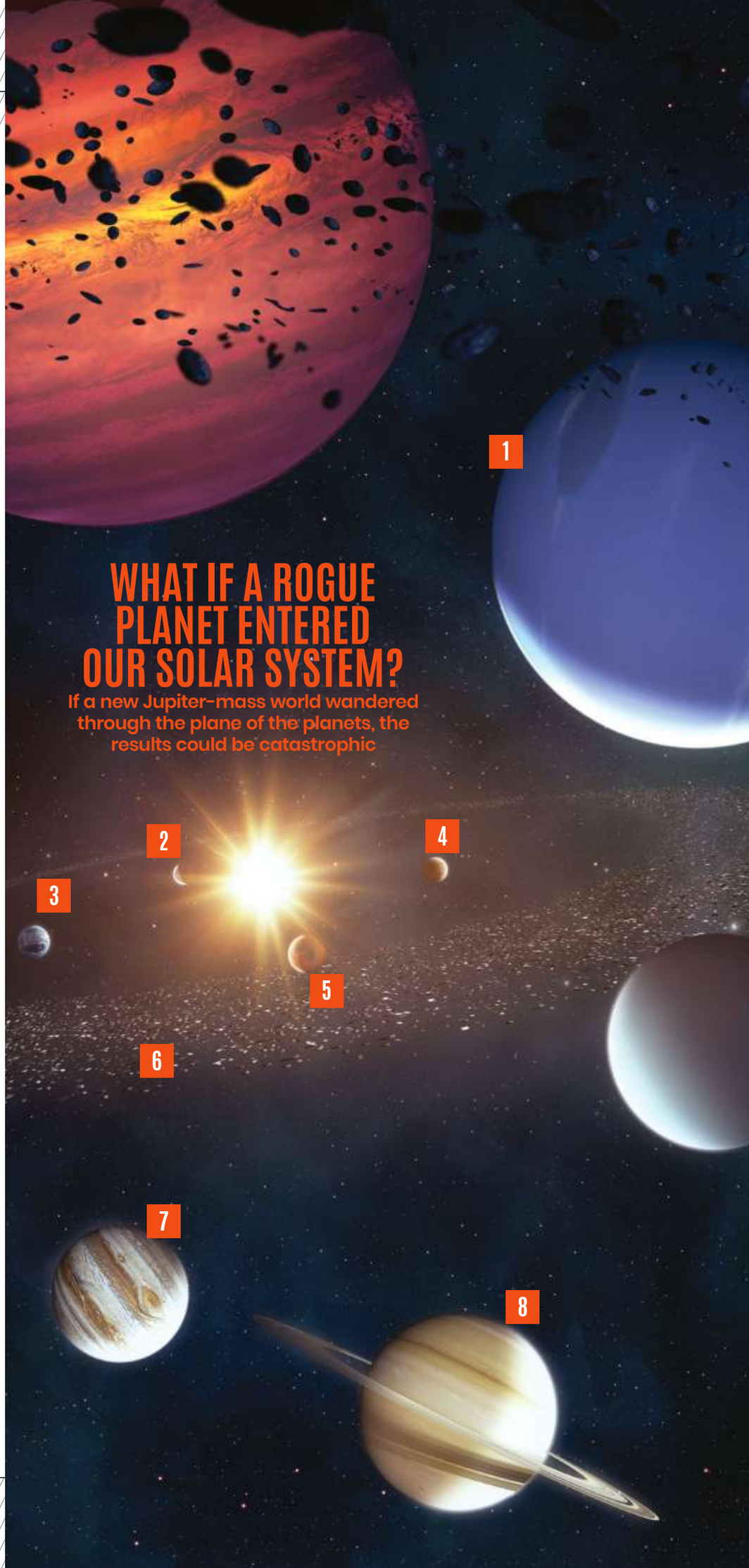
"Earth-like interstellar planets are so small, cold and faint they are difficult to detect"

should have such a hot atmosphere, but PSO J318 undoubtedly owes its torrid temperatures to its youth. Over time, the heat in its core that currently drives weather activity will dissipate, and the planet will cool into a dark deep-frozen ball of gas floating alone through space, as many others have done before. The void between the stars isn't as empty as we thought. Instead we must come to terms with the idea that it's littered with strange, dark worlds.

Giles Sparrow
Space science writer
The author of over 20 books on popular science, Giles holds a degree in astronomy and is an editor specialising in science and technology.

WHAT IF A ROGUE PLANET ENTERED OUR SOLAR SYSTEM?

If a new Jupiter-mass world wandered through the plane of the planets, the results could be catastrophic



1 Uranus and Neptune

More loosely bound to the Sun's gravity, the Solar System's outer ice giants might be most vulnerable to having their orbits disrupted, perhaps drifting away into interstellar space themselves or falling into orbit around the rogue visitor.

2 Mercury

As the closest planet to the Sun, Mercury's orbit is tightly bound by solar gravity, so it would probably survive more or less unchanged.

3 Earth

If Earth's orbit became more elliptical, it would present a severe danger to all life, as the amount of sunlight reaching the surface would become more variable and summers and winters more extreme. But the Moon might shield us from the worst effects of asteroid bombardment.

4 Venus

Venus might find its almost perfectly circular orbit disrupted into an ellipse. This could in turn upset its slow rotation period and alter the Venusian climate.

5 Mars

If the orbit of Mars was nudged closer to the Sun, surprisingly, Mars might become more hospitable as its icecaps melted and its atmosphere thickened. But it would take the brunt of the bombardment from asteroids from the main belt.

6 Asteroid belt

The countless small bodies orbiting between Mars and Jupiter would undoubtedly be disrupted. Some might be thrown out of the Solar System entirely, but others, along with comets from beyond Neptune, would rain down on the inner Solar System, causing huge impacts.

7 Jupiter

As the Solar System's largest planet, Jupiter would be best able to withstand the disruption of a rogue planet passing by. Its gravity would draw in many of the comets falling in from the edge of the Solar System.

8 Saturn

Saturn, the second most massive planet, would probably also survive, but its ring system might not withstand the disruption of the rogue planet's gravity and the bombardment of cometary debris carried with it.

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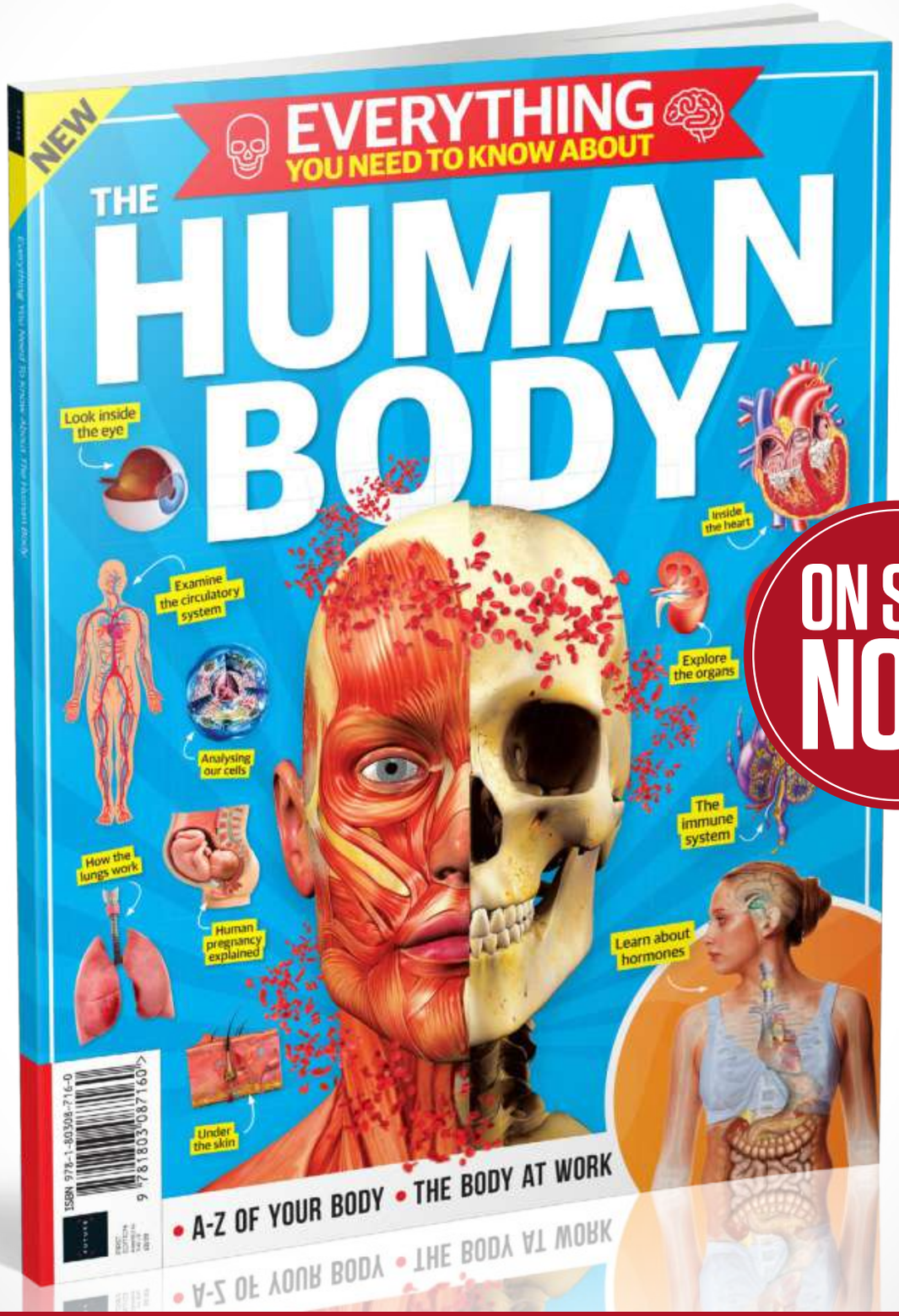

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MYSTERIES OF THE UNIVERSE

WHERE DID EARTH GET ITS WATER FROM?

Two new scientific studies have sailed researchers ever closer to discovering the source of Earth's water

Reported by David Crookes

Water covers 71 per cent of the surface of Earth, and most of it – some 96.5 per cent – is contained within our planet's oceans. The remaining 3.5 per cent is freshwater and therefore drinkable, but most of that – 68 per cent – is sealed within glaciers and ice. Such statistics are well known and equally well trodden, but they're intriguing nonetheless. After all, Earth is something of an anomaly, given that it's the only world in our Solar System with extensive, consistent and stable regions of liquid water at the surface – and no one knows exactly how this came to be.

To understand the mystery of Earth's water, you need to take into account the Solar System's snow line – the distance from the Sun beyond which water is present as ice. When the Solar System was formed, this line was between the orbits of Mars and Jupiter. Planets that formed within the line would see water turn to vapour; those beyond could accrete water ice. "It is surprising that Earth has so much water because it formed in the inner Solar System, likely within the snow line," explains Megan Newcombe, assistant professor of geology at the University of Maryland. "The Earth accreted in a region of the solar nebula that was quite near the Sun, and therefore was likely warm and relatively dry. Water ice accretion to the early Earth was probably limited."

Yet if the newborn Earth's proximity to the Sun was likely to have left it dry, how and when did the planet produce its water supply? For many years, scientists have proposed that it came in massive quantities from elsewhere in the Solar System, but proof of the exact source has eluded them.

"There is a lot of debate about the origin of Earth's water," Newcombe told **All About Space**. "Some argue that it came from comets, others argue that it came from the hydrogen-rich solar nebula, and other people argue that it came from asteroids, either from the inner or outer Solar System.

"The isotopic composition of our water matches the composition of water in meteorites, which are fragments of asteroids – this is evidence that asteroids were likely the major source of Earth's water. However, there are several varieties of meteorites and asteroids, and it is unclear which family of asteroids was responsible for delivering water to Earth."

Our blue planet is unique in the Solar System. Having liquid water on the surface limits the amount that our planet's surface temperature can vary, too

© GettyImages

EARTH'S WATER BY NUMBERS

H2O
Water molecules are made of one oxygen and two hydrogen atoms

326 MILLION TRILLION
gallons of water on Earth

96.5%
of water on Earth is in the oceans

0.001%
is in the atmosphere

3.5%
of water is freshwater

68.7%
of that is locked in ice caps and glaciers

ONE
Living beings can only use one per cent of all water on Earth

ZERO
other known Solar System planets with stale consistent surface water

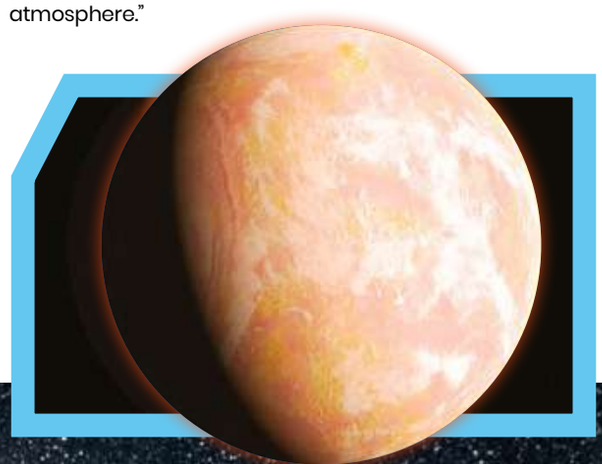
With this in mind, Newcombe led a recent study to test one such theory: that melted meteorites called achondrites could have been the source. "There are certainly a few prominent recent studies that have proposed melted meteorites as possible sources of Earth's water and other volatile elements," Newcombe adds.

These stony meteorites broke away from planetesimals – early tiny planetary bodies that collided under gravitation to form planets – and in theory could have carried water to Earth. Indeed, achondrites have collided with our planet, allowing scientists to analyse their content.

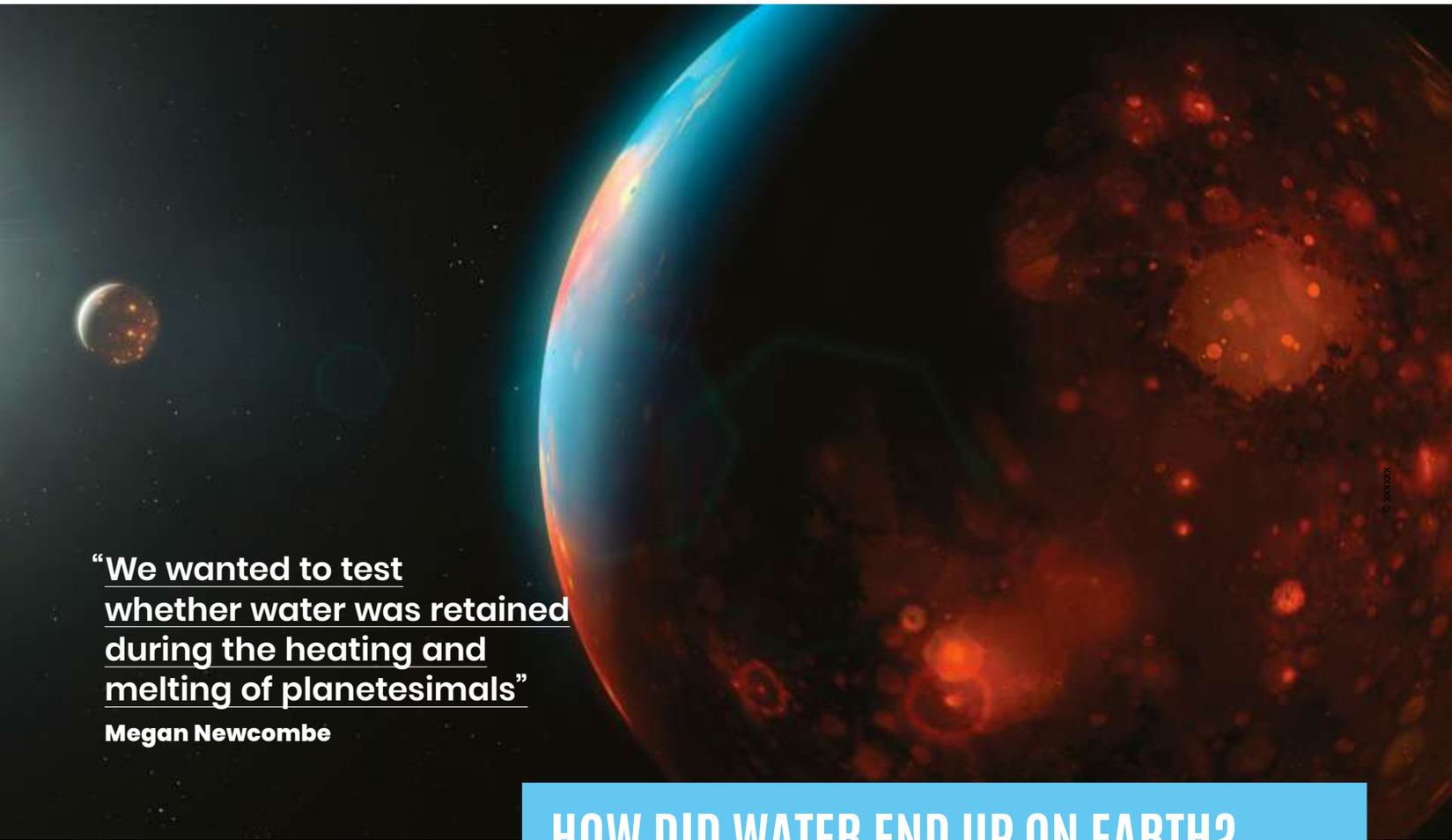
"Our study looked at the effects of thermal processing and melting on the water budget of asteroids," Newcombe says. "We wanted to study a special family of achondrite meteorites that formed in the outer Solar System, beyond the snow line. We know that the parent bodies of these meteorites would have accreted water ice, but we wanted to test whether that water was retained during the heating and melting of the planetesimals."

The special family of seven achondrite meteorites fell to Earth recently, more than 4.5 billion years after they formed. "We analysed the meteorite using a technique called secondary ion mass spectrometry," Newcombe explains. "This involves firing a cesium beam at the sample to ablate off a tiny portion of the minerals. A detector is used to count hydroxyl ions in the sample, and we are able to calculate from this how much water the meteorites contain." As you can imagine, the study was a challenge. The scientists needed to reduce terrestrial contamination, so they conducted their analyses under a high-quality vacuum for a month. They also baked the samples in a low-temperature oven to remove surface water. "We had to be very careful," Newcombe affirms.

Once done, however, the results were stark. Having analysed achondrite meteorites that had come from both the inner and outer Solar System – thereby looking at those that formed in warm and dry conditions and those in colder and icier climes – they found extremely low water content. "We found that melted meteorites are very dry, ruling out their planetesimal parent bodies as the origin of Earth's water," Newcombe says. The discovery was important. "The results of our study suggest that any water accreted to the proto-Earth would be lost during early heating, until the Earth reached the size of present-day Mars," Newcombe continues. "Once the proto-Earth grew to be larger than Mars, it would have been able to retain its water in an atmosphere."



This artist's concept shows a hypothetical exoplanet around the binary star system of Kepler-35A. But who knows how many other water worlds there are in the galaxy?



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"We wanted to test whether water was retained during the heating and melting of planetesimals"

Megan Newcombe

HOW DID WATER END UP ON EARTH?

A few theories have sought to explain water on our planet

It was delivered by asteroids

Many scientists favour the theory that water arrived on Earth via ice-rich asteroids during the Late Heavy Bombardment stage about 3.9 billion years ago. Earth would have cooled, allowing it to hold on to the resulting liquid.

It was there from the start

There is an argument that Earth could have accreted water-rich material from the nebula of gas and dust that formed the Sun. The planet would have retained water when it absorbed dust particles, allowing it to survive very high temperatures.

It made its own water

According to a study by astronomers at Carnegie and UCLA, water on Earth is the result of a chemical interaction between the magma ocean and atmosphere of our baby planet. When hydrogen moved into the metallic core of the planet, its oxidation produced water.

By ruling out melted meteorites and noting that water comprised less than two millionths of their mass, researchers have taken a step closer towards narrowing down the source of Earth's water. Moreover, they've put forward a more likely candidate – unmelted meteorites called carbonaceous chondrites, which contain about 20 per cent water by weight. That's about 100,000 times more than the melted meteorites.

"Our results suggest that unmelted material delivered water to Earth," Newcombe explains. "This material may have been in the form of very small planetesimals or in the form of larger planetesimals that accreted relatively late – around 2 million years after the start of the solar system. It has also been hypothesised that some asteroids could be melted in their interiors with an unmelted crust. These asteroids could also have delivered water-rich, unmelted material to Earth."

Such a conclusion has far-reaching effects. After all, the presence of water on Earth is important because it is thought to be a requirement for life to flourish and having liquid water on our surface limits the amount that our planet's surface temperature can vary.

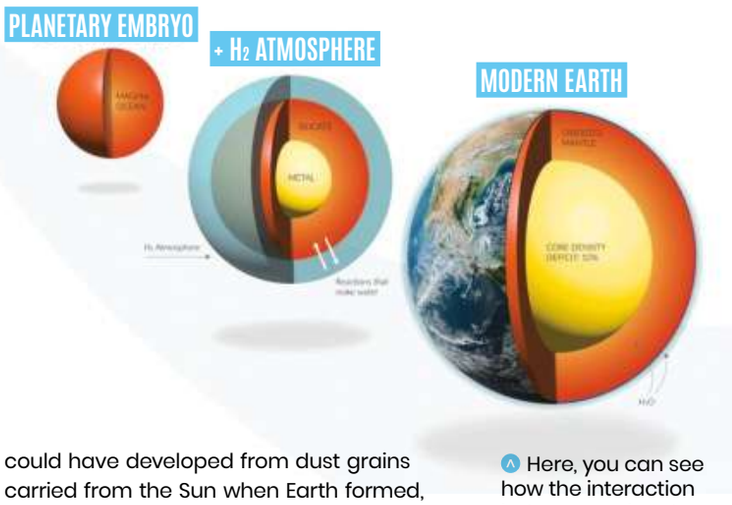
"The presence of water on the Earth tells us that planets that form within the snow line may still be water rich," she adds. "Water can be delivered from sources beyond the snow line at a late stage of planetary growth. This potentially broadens the number of potentially habitable worlds out there."

Even so, the study is only one more step towards resolving the mystery. In 2021, for instance, an international team of scientists suggested that water

During the Late Heavy Bombardment, asteroids struck Earth and other planets in the inner Solar System for as many as 200 million years. Could they have introduced water?

How Earth may have looked 4 billion years ago

© NASA/JPL-Caltech; Getty Images



could have developed from dust grains carried from the Sun when Earth formed, while another more recent study totally flips popular theories on their head.

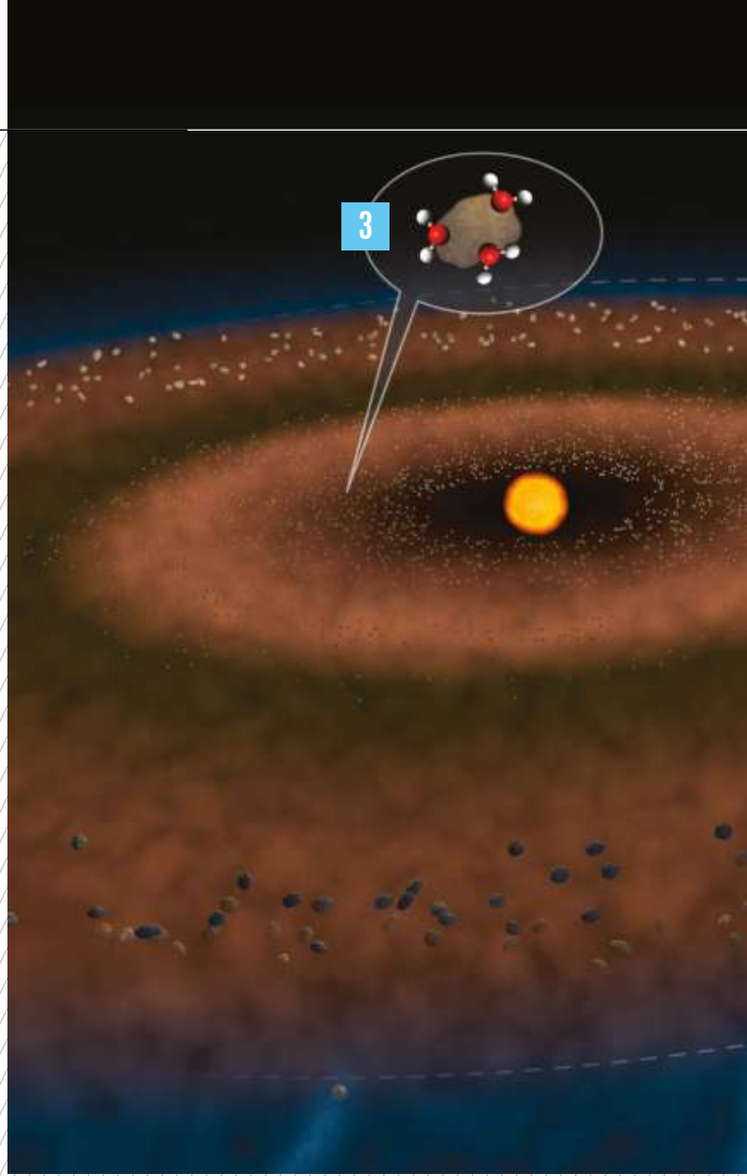
Anat Shahar, staff scientist at the Earth and Planets Laboratory at the Carnegie Institution of Washington and adjunct professor at the University of Maryland, has been working on a new mathematical model with Edward Young and Hilke Schlichting from the University of California, Los Angeles. She proposes that the source of Earth's water is much closer to home.

"Our motivation was to see what would happen to the evolution of Earth if we were to treat it as an exoplanet," Shahar told **All About Space**. "Previous studies had already shown that lots of water could form when exoplanet sized planets had hydrogen rich atmospheres, but we wanted to know if it worked for Earth as well."

Since exoplanets were discovered in the Nineties, astronomers have spent huge amounts of time studying fresh data about planetary formation. They noted that just-formed planets were often surrounded by atmospheres rich in molecular hydrogen, H2, during the first several million years of their growth, leaving an important fingerprint.

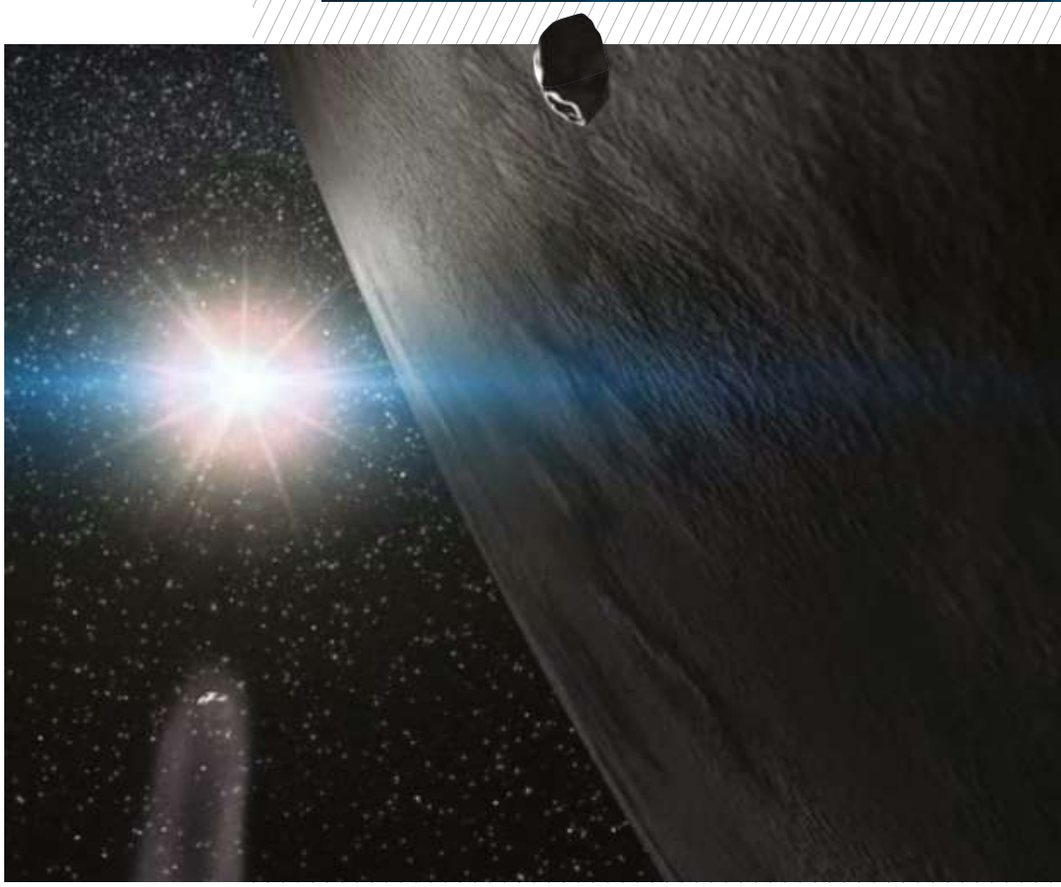
"This became apparent recently with the discovery of thousands of exoplanets in the galaxy," Shahar says. "This is significant because before this, we had only our Solar System to look at and use as a tool for understanding planet formation in general, but then suddenly we had thousands. Within those thousands, the most common type of planet was actually one we did not have in our own Solar System. So we wanted to see if what we were learning from exoplanets could also be applied to Earth."

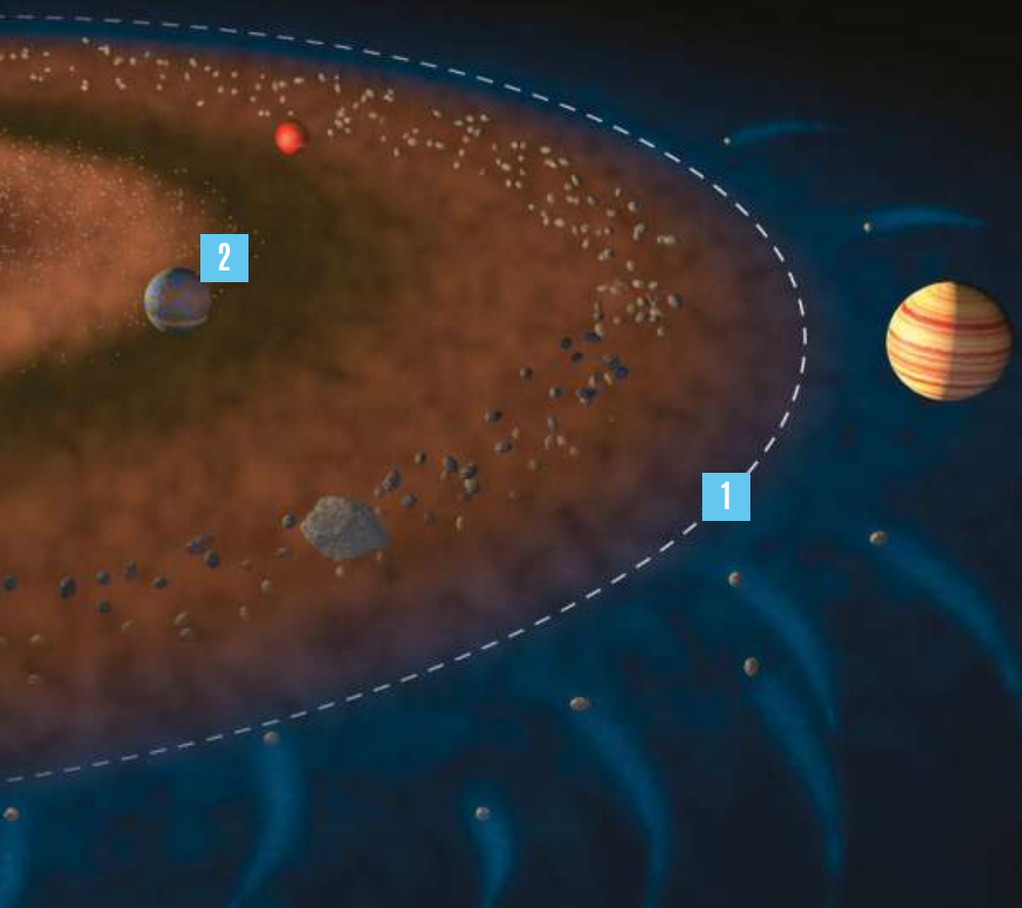
The researchers found that early interactions between Earth's magma ocean and a molecular hydrogen proto-atmosphere that may have enveloped our young world led to it becoming a watery world. In other words, water did not



Here, you can see how the interaction between a planetary embryo and an atmosphere rich in hydrogen could cause a chemical reaction that resulted in the formation of an abundance of water

Water on an asteroid was first discovered in 2010 on a 120-mile rock called 24 Themis, spotted beyond Mars





DELIVERING WATER

Just how would water have arrived on Earth from elsewhere?

1 The snow line

Planet-forming disks have a boundary called the snow line, which marks a distance – in our case about about 5 AU from the Sun – at which the temperature drops sufficiently for volatile compounds to begin to condense into ice.

2 Early planet formation

The thinking in this situation is that because Earth formed within the inner Solar System (inside the snow line), it would not have been able to accrete sufficient water ice. It would have turned to vapour very quickly.

3 Spying the source

Some time later, rocky objects with water molecules attached to them struck the Earth and deposited liquid. Nobody can yet say for certain exactly which rocky objects did this, but a recent study rules out melted meteorites.

© Jack Cook/Woods Hole Oceanographic Institution; Edward Young/UCLA and Katherine Cain/Carnegie Institution for Science; Gabriel Pérez, Servicio MultiMedia, Instituto de Astrofísica de Canarias, Tenerife, Spain; James St. John

necessarily have to come from elsewhere, but was formed on Earth itself as a byproduct of chemistry.

"The model takes a hot molten Earth, surrounds it with hydrogen, and then lets all the chemistry play out between the atmosphere, mantle and metallic core," Shahar says. "Some of the hydrogen goes into the core, as well as some silicon and oxygen. Lots of water is produced that goes into the mantle and atmosphere. The oxidised state mostly comes from the incorporation of silicon into the metallic core of the planet."

The result is an abundance of water, even if the rocky material that collided to form Earth was dry. "Our methods were really simple: we modelled all the chemical reactions with equilibrium thermodynamics," Shahar continues. "I think the biggest challenges were trying to make sure that we replicated many of Earth's features. This is hard because there are so many!"

It's certainly a head-turning theory. It also doesn't rule out other sources – it just says that those may well have been far less important, although some studies have suggested that water inside carbonaceous chondrites doesn't match the chemical footprint of Earth's water.

"Our model does not preclude water coming from asteroids or comets," Shahar says. "We just provide an explanation that is able to explain the water content of Earth, as well as other characteristics of the planet."

Intriguingly, hydrogen-rich atmospheres are common around newly formed rocky planets outside our Solar System. It follows, then, that Dr Shahar's study could have huge implications.

"If we figure where Earth got its water, maybe we can figure out which other planets would have liquid water," she says. "It could start us down the path of looking for life."

Even so, caution is advised. "Astronomers have found hydrogen-rich atmospheres around exoplanets, and that alone is not a marker for life – it's a natural consequence of planet formation," Shahar says. "By showing that Earth could have gone through this stage, we are suggesting super-Earths that are no longer surrounded by that hydrogen gas could have formed water in their history."

^ It is likely that carbonaceous chondrites brought water to Earth, but whether or not they brought it all is very much questioned

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

FOCUS ON

URANUS' MOONS MAY HAVE OCEANS OF SALTY WATER

If the moons had benefited from long-term heating, then they could have maintained a thick ocean

Reported by Sharmila Kuthunur

The four biggest moons of Uranus may harbour salty oceans below their frozen surfaces. Scientists taking a fresh look at 40-year-old data sent home by NASA's Voyager 2 spacecraft say that the satellites Titania and Oberon, which orbit the furthest from Uranus among the group, may be home to buried oceans 30 miles (50 kilometres) deep, while those of Ariel and Umbriel may be 19 miles (30 kilometres) deep. The new research explains how the persistent internal heat of the Uranian moons and a few chemicals could make them watery worlds despite their location in the frigid outer reaches of the Solar System. "Finding oceans in the Uranian moons would increase the prospect that [...] ocean worlds are frequent in our Solar System, and maybe – by extension – in other solar systems," Julie Castillo-Rogez, a planetary scientist at NASA's Jet Propulsion Laboratory in California, said.

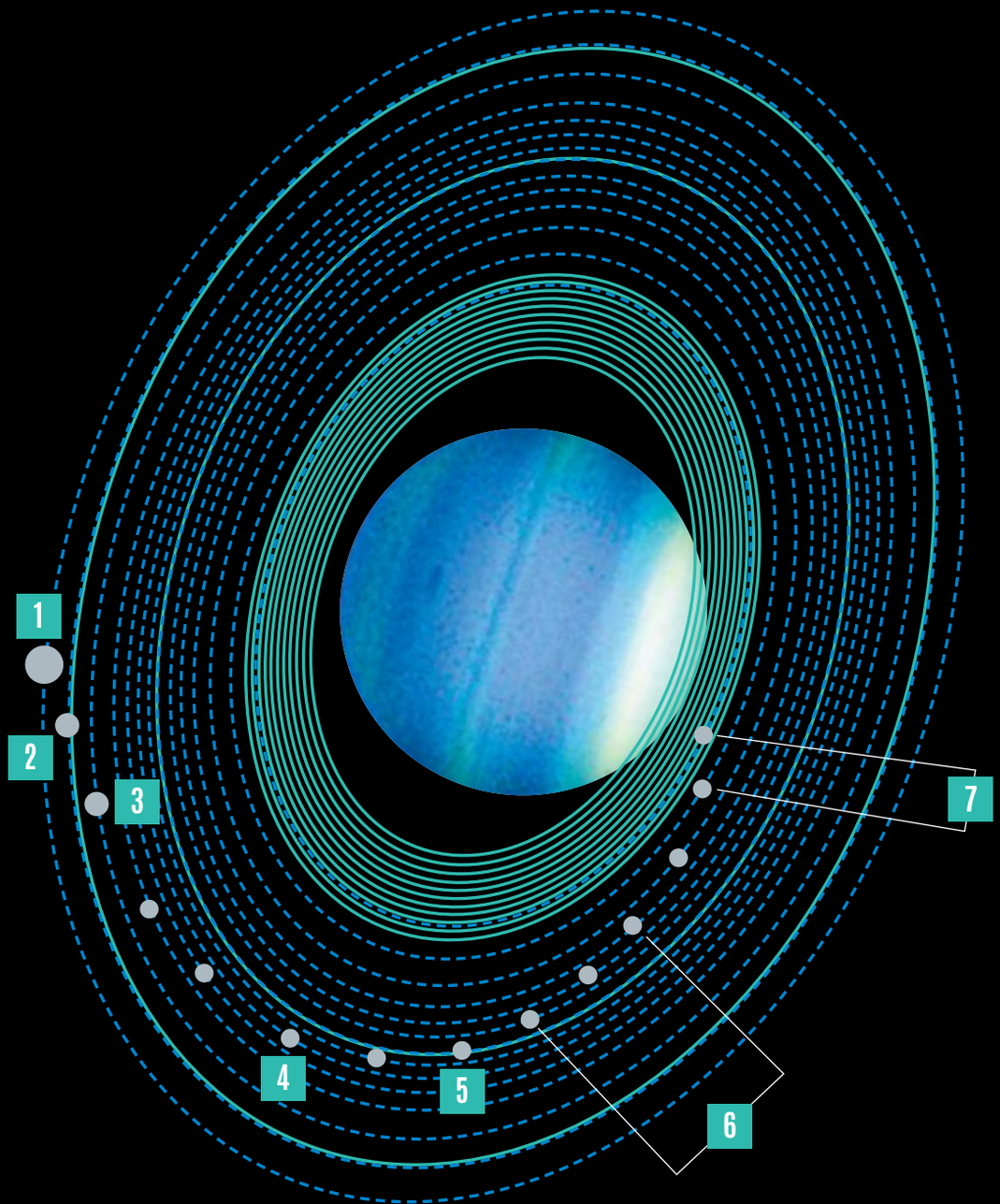
Early in their histories, Uranus' five largest moons – Titania, Oberon, Ariel, Umbriel and Miranda – likely hosted substantial oceans ranging from 62 miles to 90 miles (100km to 150km) deep, researchers said. "If the moons had benefited from long-term heating from their planet, then they could have maintained a thick ocean". For example, the Jupiter moon, Europa, and Saturn's Enceladus, both of which harbour big subsurface oceans, flex their innards and icy crusts in response to the strong gravitational pull from their host planets. Scientists think that this tidal heat helps the moons maintain their subsurface water as a life-friendly liquid. But Uranus's tug is far weaker than that of Saturn or Jupiter, so oceans on even the planet's four largest moons are "mostly frozen by now," Castillo-Rogez said.

To understand more about how Uranus's moons may have evolved, her team built a model by gathering findings from NASA missions that studied other ocean worlds. These included Saturn's moon, Enceladus, as observed by the Cassini mission; the dwarf planet, Ceres, as revealed by Dawn; and Pluto's largest moon, Charon, which New Horizons observed during its epic Pluto flyby in 2015.

The model revealed that the Uranian moons likely hold "thin oceans with high salt concentrations." This would be thanks to limited internal heat left over from their births, as well as ammonia, whose antifreeze nature helps keep water in its liquid form even in very low temperatures. Researchers estimate that the oceans on these Uranian moons have about 150 grams of salt for every litre of water. In comparison, Utah's Great Salt Lake is twice as salty, but life still manages to thrive in and around it. The jury is out on the ocean potential of Uranus's fifth-biggest moon, Miranda. Although previous research hinted at a hidden ocean to explain intriguing charged particles blasted into space, Miranda is so small that its internal ocean likely froze a few million years after it formed.

So far, Uranus has been briefly visited by only Voyager 2 – which spotted 10 new moons and a couple of new rings – during its January 1986 flyby. But Uranus may get more attention in the future, in part because exoplanet research has revealed that ice giants are among the most common, yet least understood, planets in the galaxy.

NASA is developing a potential mission to the planet, currently given the placeholder name of Uranus Orbiter and Probe (UOP). As that moniker suggests, UOP would include an orbiter to gather data about the ice giant and its moons from afar, and a probe that would drop into the planet's atmosphere for first-hand information.



THE ORBITS OF THE MOONS

Orbit
Ring

1 Miranda
The smallest and innermost of Uranus' five major moons, Miranda orbits the planet at around 129,390 kilometres (80,400 miles).

2 Mab
Although photographed by Voyager 2, Mab's existence was not revealed until 2003. Its size is unconfirmed, but we know that it is highly perturbed by the orbits of neighbouring moons.

3 Puck
Puck is the largest inner moon of Uranus, and lies between the rings and Miranda, the first of the larger moons.

4 Cupid
Discovered in 2003, Cupid is the smallest of the inner moons at just 18 kilometres (11.2 miles) in diameter.

5 Portia
The second largest inner moon, Portia heads a group of moons with similar orbits. It has a diameter of about 140 kilometres (87 miles).

6 Juliet, Desdemona and Cressida
Little is known about these small neighbouring moons, but their chaotic orbits may result in collisions within 100 million years.

7 Ophelia and Cordelia
These innermost known moons serve as shepherd satellites – defining the inner and outer edges of Uranus' Epsilon ring.

THE MAJOR MOONS

Miranda
The innermost and smallest of Uranus' five major moons has a diameter of roughly 472km (290 miles).

Ariel
The fourth largest moon, Ariel has the third greatest mass. Voyager 2 imaged about 35 per cent of its surface.

Umbriel
Umbriel has the darkest surface of the Uranian moons, and is one of the most heavily cratered.

Titania
Titania is the eighth largest moon in the Solar System, with a diameter of around 1,580km (980 miles).

Oberon
Oberon is the outermost of the five major moons and is partially outside of Uranus' magnetosphere.

© NASA

EXOPLANETS

What do we know about the surface of super-Earth Kepler-452b?

We know very little about what the planet is like. What we do know is that the star is essentially the same temperature as the Sun - about 5,500 degrees Celsius (9900 degrees Fahrenheit) - and just a little bit bigger than the Sun. Its estimated age is 6 billion years old, so it's about 2 billion years older than our own star. We know that this planet is about five per cent further from its star than our planet is from the Sun. That's what makes it interesting – it's the closest analogue we have to the Sun-Earth system outside our own Solar System.

In terms of the surface of the planet, we don't have a mass measurement, so all we have to go on to understand whether this planet is likely to be rocky or not is to look at the populations of other exoplanets we have found. It's kind of like looking at a classroom of children and measuring their heights and weights, then the next day Sally comes to school, but the balance is broken, so we can't measure her weight. However, we can still measure her height and then predict her weight based on the weights of the other students we measured. The same thing is true here - we measure the size of this planet and compare it against the sizes of other exoplanets for which we do have better measurements. Our best guess at this planet is about five times the mass of Earth, and there's a 50 to 60 per cent chance that it's rocky. Kepler-452b is on the dividing line between rocky and gassy. With an Earth radius of 1.6, the surface gravity would be about twice what we are experiencing right now.

Jon Jenkins is a former team member of the Kepler Space Telescope, NASA's first mission capable of finding Earth-sized planets orbiting Sun-like stars

"It's the closest analogue we have to the Sun-Earth system outside our own Solar System"

ASTEROIDS

What sort of measures can we take to protect against asteroid impacts?

What's important is finding the larger asteroids before they find us, and conducting characterisation missions to study any potentially hazardous asteroids. Mitigation measures to minimise the effects from an impact event include the kinetic impactor technique, which was tested and proven to be successful during the DART mission; the gravity tractor, and a nuclear device. Civil protection arrangements, such as evacuation and shelter, are required as a contingency in the unlikely event that deflection methods fail.

Debbie Lewis is a Resilience Advisor for the civil protection response to asteroid impact events

< The star of Kepler-452b is bigger than our own Sun

< The kinetic impactor technique was tested on the DART mission

v The Curiosity rover takes a selfie on Mars

ASTRONOMY

What would you say is the biggest scientific space breakthrough?

When we see something like Curiosity on Mars, the idea that we have incredibly clear images of the surface of the Red Planet is amazing, even though it's very parochial in terms of the size of our galaxy.

I think there are also remarkable things when you look at the longevity of space exploration. Voyager was the fastest human-made object to go into space, and the fact that I was eight when that was launched and I was over 40 when it reached what we consider the edge of our Solar System is incredible. Those signals, those images that have been gathered over a period of decades, allow us to start to become familiar with the surroundings of our Solar System.

Robin Ince is one of the best-known voices for science in the UK. He presented the popular BBC Radio 4 show *The Infinite Monkey Cage* with physicist Brian Cox

© Getty Images; NASA

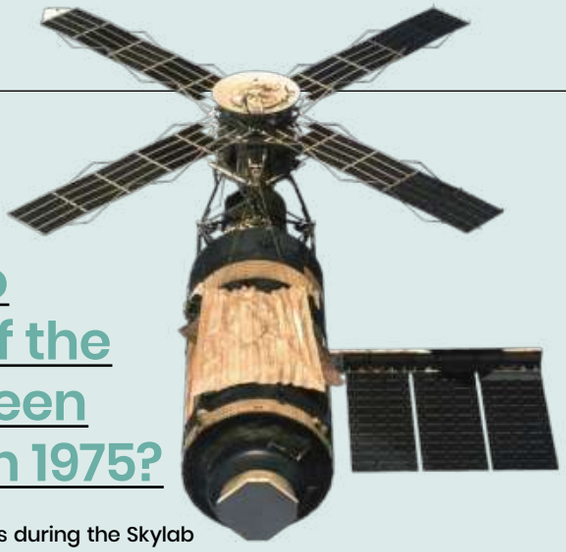
SPACE EXPLORATION

What's involved in training to become an astronaut?

As an astronaut, you get trained to do all kinds of things: learn to fly in a high-performance aeroplane, learn the systems of the Space Shuttle and the Space Station, and learn how to work as a team in simulations. You're practising, practising and practising. My primary job on my missions was that I worked the [Canadarm] robot arms a little bit. However, my number one job in space ended up being the spacewalker. To do that, you piece together different experiences, including stuff in virtual reality, and we had lessons where we had to learn about the spacesuit and the techniques [we'd be employing in space] and so on.

It all seemed to come together in our big pool, the neutral buoyancy laboratory. It's 100 feet [30 metres] wide, 200 feet [61 metres] long and 40 feet [12 metres] deep. It's the largest pool in the world, and you can fit an entire Space Shuttle inside it, or even a Hubble Space Telescope, as well as an International Space Station. You can practise what you're going to do in space in the water. You're floating in a water column like you'd be floating in space. For me, those were the big events, and many hours, days, weeks and months of my life add to my days at work in the buoyancy laboratory. It was a wonderful experience, training for a spacewalk.

Mike Massimino is a former NASA astronaut and professor of mechanical engineering at Columbia University



SPACE EXPLORATION

What was it like to witness the end of the Space Race between the US and USSR in 1975?

America had been working with the Russians during the Skylab missions [in the early Seventies] and they visited our control centre, so I knew we were working on a joint mission with the Soviets. It was kind of funny, having been a soldier of the Cold War to then be involved with Russia at that time in 1975 [the Apollo-Soyuz Test Project]. I can recall on May Day [1 May] standing beside Lenin's tomb with Brezhnev watching the May Day Parade, and I thought, "Boy, how did we get here?'. But you know, working with the cosmonauts was great. We were the first ones to ever go to their launch site, and some pilots the world over became very good friends with some of the cosmonauts.

Robert Laurel Crippen served on the support crew for Skylab and the Apollo-Soyuz Test Project, and piloted Columbia, the first ever Space Shuttle mission

^ The US worked with Russia on the Apollo-Soyuz Test Project

> A lot of big discoveries have been made at radio wavelengths

v Live formed on Earth after the planet began to cool down

LIFE

How did life form on Earth?

For hundreds of millions of years, many meteorites, asteroids and comets bombarded Earth. Life would not have formed in these early times because our planet was too hot and it would have been very dry, so there would have been no possibility.

At around the same time that the rocks stopped falling, Earth started to cool down and the first signs of an ocean started to appear. We even have fossils that show evidence of life within a few hundred billions of years – that's about the same time that life could have possibly occurred here. How life came to evolve on our planet is strong evidence that life can evolve elsewhere in the universe. Intelligent life – that's us – has only really turned up quite recently. We ourselves are made up of star material, as stars that explode send chemical material into space.

John Mather is an astrophysicist at the NASA Goddard Space Flight Center and is the project scientist of the James Webb Space

© Getty Images; NASA

ASTRONOMY

Why do some telescopes operate in radio wavelengths?

Well, there's particular science that can only be done in radio wavelengths. You just need to look back at the last 30 or 40 years or so of astronomy – a lot of the big discoveries have been made at radio wavelengths, particularly the pulsars, which were discovered in the UK and not have been done in any other wavebands.

I'd say that this is a very big example of needing to study the universe in radio wavebands. Things like looking at complex molecules, which are very interesting for people looking for life in the universe, is another example, and one of which is going very well in the radio wavelengths.

Looking back in time is also very good in long radio wavelengths, since they can see through all of the obscuring matter in space in order to go way back to the beginning of the universe, which can be very hard to do at optical wavelengths and other wavelengths. It's the way that a lot of astronomy has been done.

Tyler Bourke is one of the scientists charged with bringing the Square Kilometre Array (SKA) to life

WHAT'S IN THE SKY?

What to look out for during this observing period

In this issue...

80 What's in the sky? This exciting observing period brings lighter skies and tantalising targets to observe

82 Planetarium Where you can find the planets this month and the phases of the Moon

84 Month's planets Venus continues to dominate the sky and takes part in a striking conjunction

86 Moon tour This month, we help you find one of the Moon's best hidden gems

87 Naked eye and binocular targets The constellations of Hercules, Scorpius and Corona Borealis are ideal targets

88 Deep sky challenge The nights are still short, but there are plenty of things to see if you're a night owl

90 The Northern Hemisphere An impressive array of galaxies, star clusters and nebulae grace the skies

92 Review We put the portable and versatile Olympus 8x25 WP II binocular to the test

96 In the shops Our pick of the best gifts and accessories for astronomy and space fans

17 JUNE
Saturn enters retrograde motion, shining at magnitude +0.7 in Aquarius

18 JUNE
Open cluster IC 4665 is well placed for observation in Ophiuchus (V)

21 JUNE
June solstice

22 JUNE
The Moon and Mars make a close approach, passing within 3°34' of each other in Leo

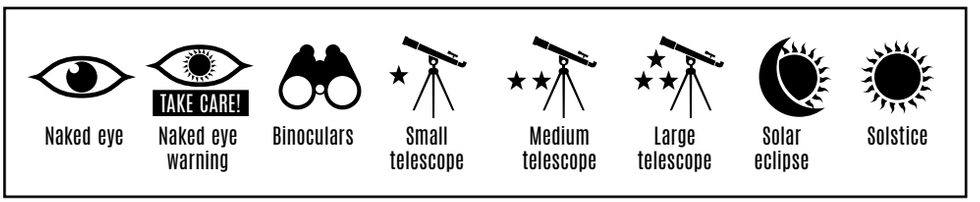
Red-light friendly
In order to preserve your night vision, you should read our observing guide under red light

27 JUNE
The June Bootid meteor shower reaches its peak

30 JUNE
Neptune enters retrograde motion, glowing at magnitude +7.9 in Pisces

30 JUNE
The Moon passes in front of the star α (Dschubba), creating a lunar occultation

1 JULY
Mars and Venus make a close approach, passing within 3°33' of each other in Leo



22 JUNE

The Moon and Venus make a close approach, passing within 3°31' of each other in Cancer

23 JUNE

Lagoon Nebula (Messier 8) is well placed in Sagittarius

29 JUNE

Open cluster NGC 6633 is well placed for observation in Ophiuchus

1 JULY

Globular cluster Messier 22 is well placed for observation in Sagittarius

2 JULY

Open cluster IC 4756 is well placed for observation in Serpens

7 JULY

The Moon and Saturn make a close approach – within 2°25' of each other in Aquarius

9 JULY

Venus reaches its greatest brightness in the evening sky, dazzling at magnitude -4.5

11 JULY

The Moon and Jupiter make a close approach – within 2°03' of each other in Aries

12 JULY

Comet 185P/Petriew reaches perihelion and is predicted to reach magnitude +11.4

"Venus reaches its greatest brightness in the evening sky, dazzling at magnitude -4.5"

Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

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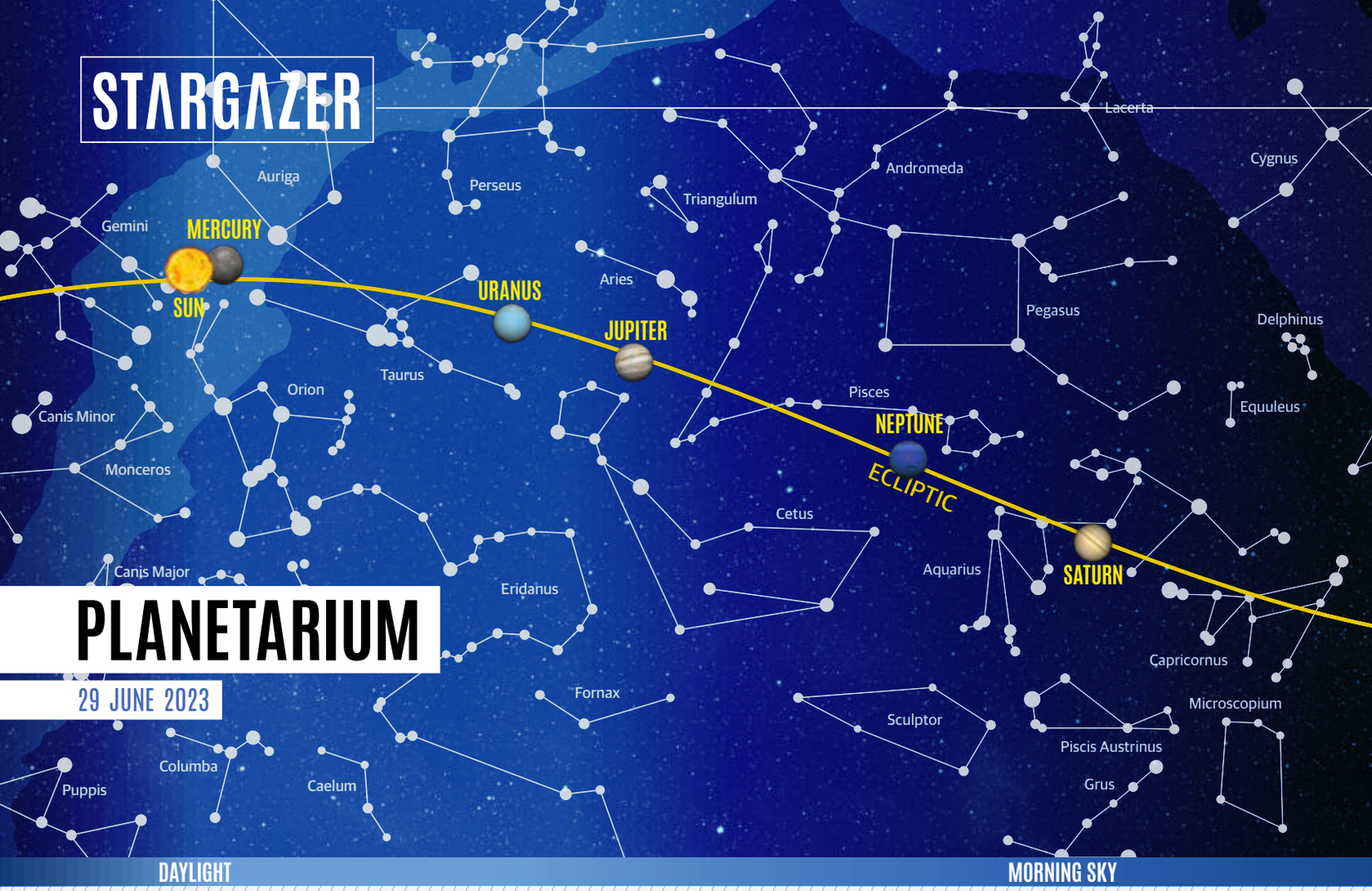


MOON CALENDAR

* The Moon does not pass the meridian on 2 July

15 JUN	16 JUN	17 JUN	18 JUN
8.0%	3.2%	0.6%	NM 0.2%
02:48 18:52	03:09 20:10	03:37 21:22	04:15 22:22

19 JUN	20 JUN	21 JUN	22 JUN	23 JUN	24 JUN	25 JUN
2.0%	5.6%	11.0%	17.8%	25.8%	34.8%	44.4%
05:06 23:09	06:08 23:42	07:18 --:--	00:07 08:30	00:25 09:42	00:39 10:53	00:51 12:04

26 JUN	27 JUN	28 JUN	29 JUN	30 JUN	1 JUL	2 JUL
FQ 54.4%	64.5%	74.3%	83.3%	90.9%	96.5%	--.-%*
01:01 13:15	01:12 14:28	01:23 15:44	01:37 17:05	01:55 18:31	02:21 19:56	02:59 21:13

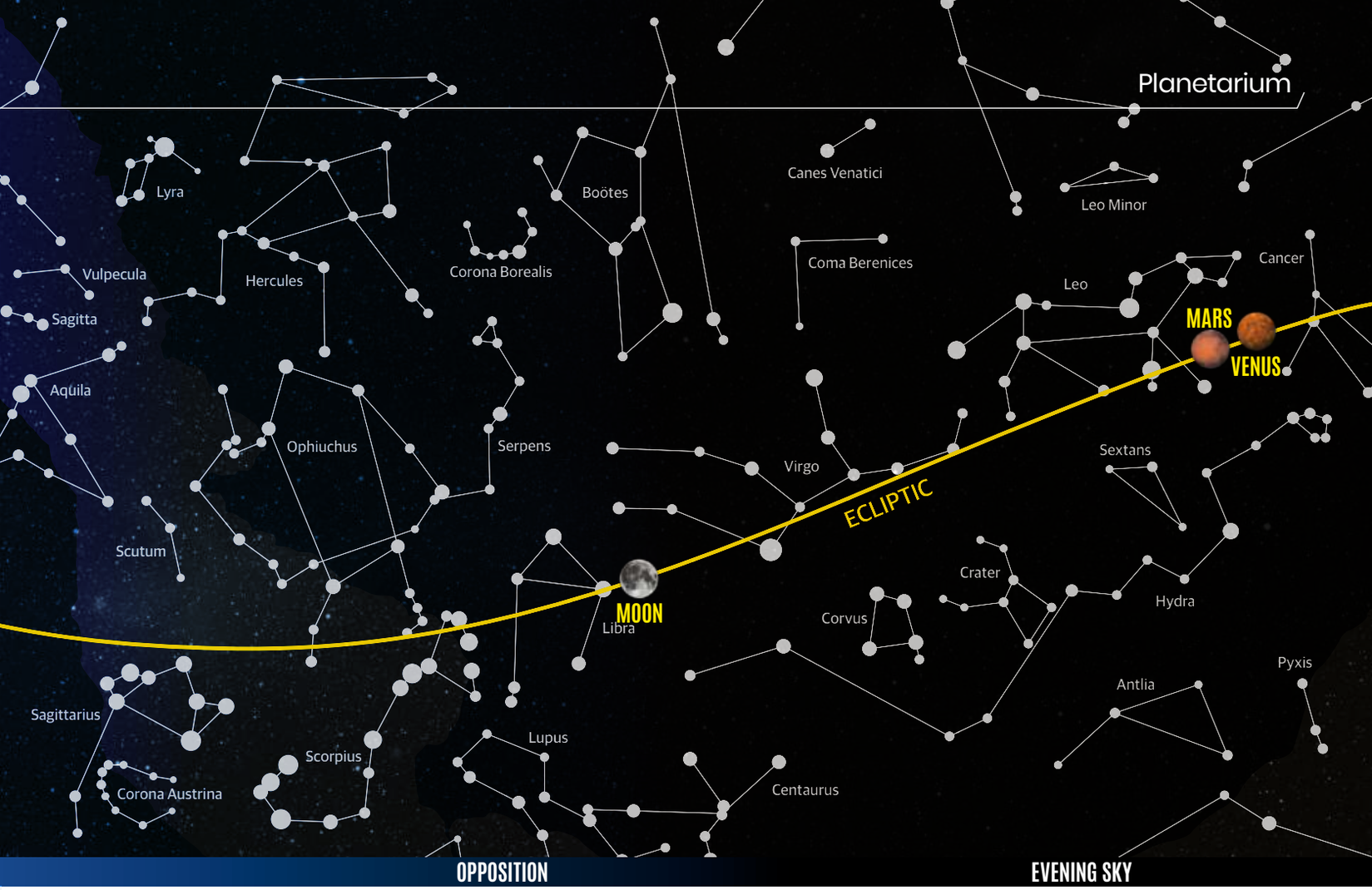
3 JUL	4 JUL	5 JUL	6 JUL	7 JUL	8 JUL	9 JUL
FM 99.5%	99.4%	96.1%	89.8%	81.2%	70.9%	59.6%
03:55 22:14	05:12 22:55	06:42 23:24	08:16 23:44	09:48 --:--	00:00 11:15	00:13 12:39

10 JUL	11 JUL	12 JUL	13 JUL
TQ 48.2%	37.1%	27.0%	18.1%
00:26 14:00	00:39 15:21	00:54 16:41	01:14 18:00

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE

PLANET POSITIONS

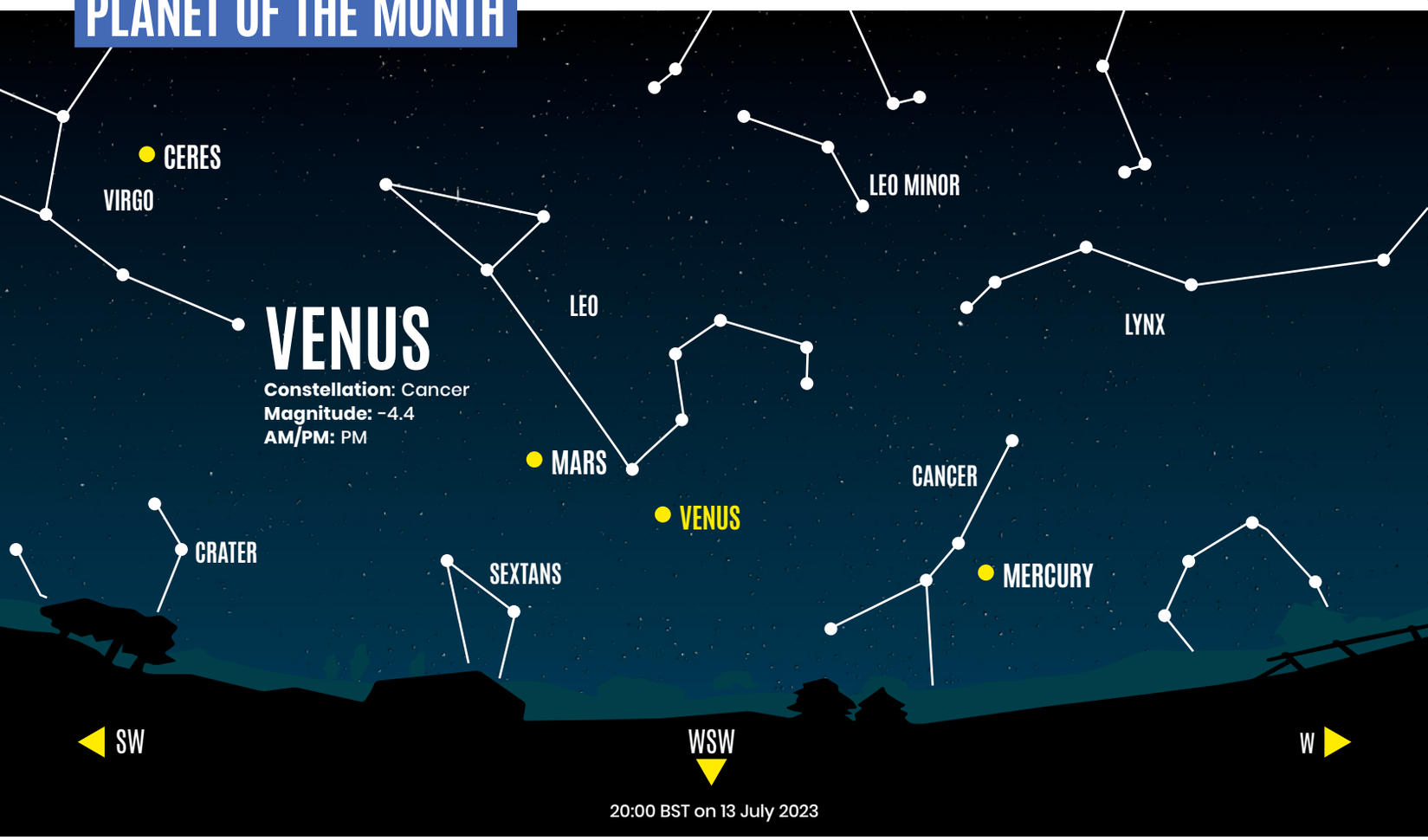
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
15 JUNE	04h16m15s	+19°45'05"	Taurus	-0.7	03:51	19:36
22 JUNE	05h12m31s	+22°46'43"	Taurus	-1.3	03:58	20:25
29 JUNE	06h17m30s	+24°21'17"	Gemini	-2.1	04:24	21:14
6 JULY	07h23m48s	+23°45'28"	Gemini	-1.6	05:07	21:49
13 JULY	08h23m51s	+21°12'46"	Cancer	-0.9	05:57	22:03
15 JUNE	08h44m54s	+20°08'33"	Cancer	-4.4	08:16	00:07
22 JUNE	09h07m45s	+18°00'09"	Cancer	-4.4	08:25	23:48
29 JUNE	09h27m10s	+15°44'50"	Leo	-4.4	08:31	23:27
6 JULY	09h42m27s	+13°29'18"	Leo	-4.5	08:31	23:01
13 JULY	09h52m46s	+11°21'06"	Leo	-4.5	08:26	22:32
15 JUNE	09h09m05s	+17°47'45"	Cancer	+1.7	08:55	00:16
22 JUNE	09h25m34s	+16°28'59"	Leo	+1.7	08:52	23:57
29 JUNE	09h41m58s	+15°05'10"	Leo	+1.7	08:49	23:37
6 JULY	09h58m17s	+13°36'43"	Leo	+1.7	08:47	23:18
13 JULY	10h14m32s	+12°03'59"	Leo	+1.7	08:44	22:58
15 JUNE	02h16m08s	+12°27'59"	Aries	-2.2	02:35	16:53
22 JUNE	02h21m24s	+12°53'52"	Aries	-2.2	02:10	16:33
29 JUNE	02h26m23s	+13°17'46"	Aries	-2.2	01:45	16:13
6 JULY	02h31m04s	+13°39'37"	Aries	-2.3	01:20	15:52
13 JULY	02h35m25s	+13°59'18"	Aries	-2.3	00:55	15:31
15 JUNE	22h36m47s	-10°26'40"	Aquarius	+0.9	00:55	11:15
22 JUNE	22h36m48s	-10°28'21"	Aquarius	+0.9	00:28	10:47
29 JUNE	22h36m30s	-10°31'47"	Aquarius	+0.8	00:01	10:19
6 JULY	22h35m54s	-10°36'55"	Aquarius	+0.8	23:33	09:51
13 JULY	22h35m01s	-10°43'38"	Aquarius	+0.7	23:05	09:22

THIS MONTH'S PLANETS

Venus takes part in a striking conjunction this summer

PLANET OF THE MONTH



Venus is our planet of the month again because this is the last month when it will be dominating the sky. It's been a striking sight in the evening sky for the past few months, but now it is edging back towards the Sun and will soon be lost from view, so it only seems fair to focus on it one last time before another planet takes its place here at the top of the page.

At its best, Venus shines brighter than any other planet in the sky. It is Earth's closest planetary neighbour, and because it is very similar in size to our own world it is often called 'Earth's Twin'. However, that is a very inaccurate comparison, because whereas Earth is a lush green and blue world abundant in life, Venus is a barren, heat-blasted rock with poisonous air, deadly heat and crushing atmospheric pressure at its surface. Ironic then that its beautiful appearance in the sky led to it being named after the Goddess of Love.

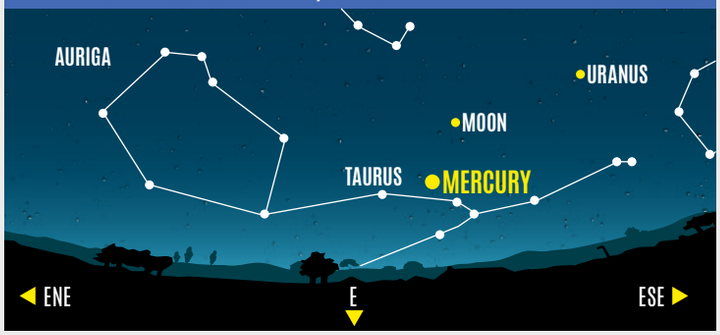
At the start of our observing period Venus will be found low in the western sky after sunset, a bright spark of light shining on the outskirts of the 'Beehive' star cluster, M44. It will then be setting some two and a half hours after the Sun, but as the days pass it will set a little earlier each evening, until it sets just 90 minutes after the Sun by July 1st. By then it will have crossed into Leo and will be shining just three and a half degrees away from fainter, ruddier-hued Mars.

By 13 July Venus will be found much lower in the west as the sky darkens, and will be setting less than an hour after the Sun. It will have two planets nearby for company too – Mars will be shining to its upper left, and Mercury will be shining down to its lower right. All three worlds will be visible to the naked eye, as long as your horizon is clear.

If your sky is clear after sunset on the evening of 22 June, you'll be treated to a very striking sight – a thin 'New' crescent Moon will be shining to the upper left of Venus, with Mars glowing between the two.

It's been great having Venus blazing in our evening sky over the past few months, but it's ready to surrender the spotlight to another world. Before it is lost in the Sun's glare, enjoy looking at this beautiful 'Evening Star' a few more times, imagining what it would be like to stand on its rock strewn, furnace-hot surface, beneath its lemon curd-coloured sky, missing the fluffy white clouds and rain of Earth.

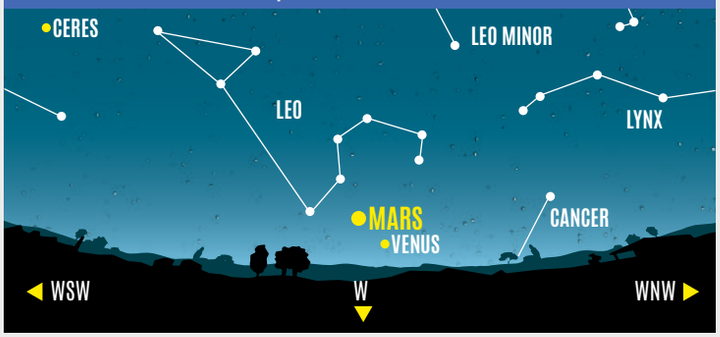
MERCURY 07:00 BST on 16 July 2023



Constellation: Taurus **Magnitude:** -0.7 **AM/PM:** AM

At the start of our observing period Mercury will be a morning star, rising only half an hour before the Sun. Look out for a very thin crescent Moon shining close to Mercury before sunrise on 16 June. Each morning it will be closer to the rising Sun until we lose sight of it by 1 July. After that Mercury will move into the evening sky.

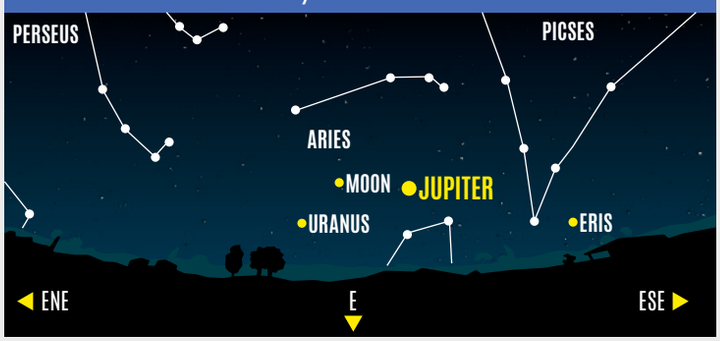
MARS 22:00 BST on 1 July 2023



Constellation: Cancer **Magnitude:** +1.7 **AM/PM:** PM

Mars will be a faint evening star through the month ahead. In mid-June Mars will be setting more than two hours after the Sun, visible in a dark sky for a while before setting. As the month progresses Venus will draw much closer to Mars. By 13 July, Mars will have moved across into Leo, to shine very close to its brightest star, Denebola.

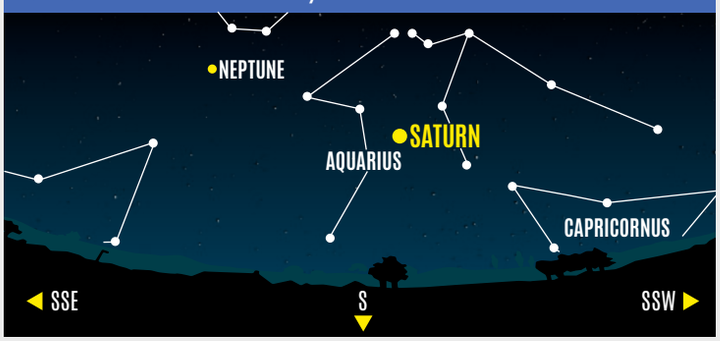
JUPITER 04:00 BST on 12 July 2023



Constellation: Aries **Magnitude:** -2.1 **AM/PM:** AM

At the start of our observing period Jupiter, the largest planet in the solar system, will be a morning object, rising in the north east around two hours before the Sun and visible to the naked eye as a yellow-white star. By 1 July Jupiter will be rising two and a half hours before sunrise, which will increase to three hours by 12 July.

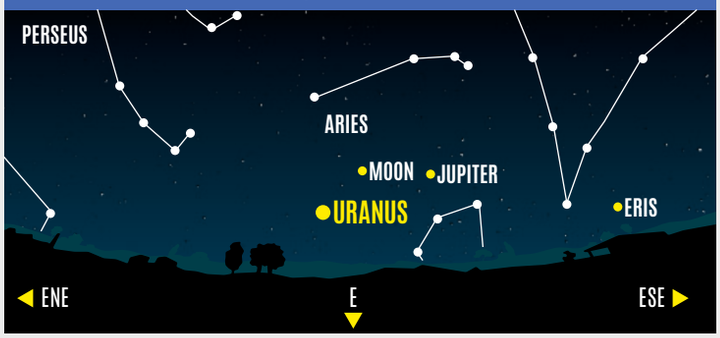
SATURN 04:00 BST on 15 July 2023



Constellation: Aquarius **Magnitude:** +0.9 **AM/PM:** AM

Through June and into July Saturn will be a morning object, visible to the naked eye as a yellow-white star. By 1 July Saturn will be rising four hours before the Sun, just after midnight, and by mid-July it will rise around 11:20pm, technically making it an evening object, even though it won't be obvious to the eye until some time after.

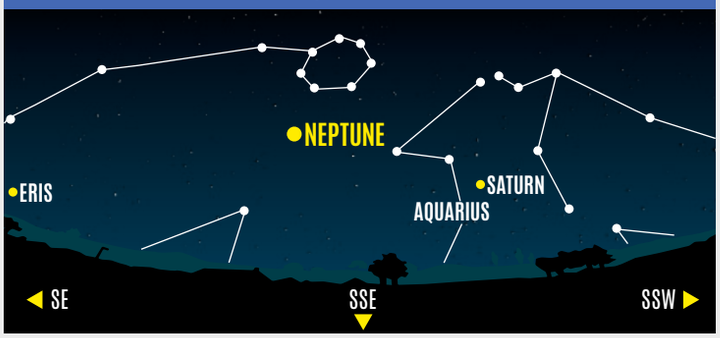
URANUS 04:00 BST on 12 July 2023



Constellation: Aries **Magnitude:** +5.8 **AM/PM:** AM

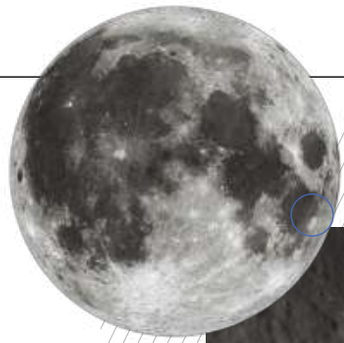
Uranus will spend the month ahead in the morning sky, embedded in the constellation of Aries. With a magnitude of 5.8 this faraway planet is visible to the dark-adapted naked eye under a dark sky, but you'll need a pair of binoculars to pick it out and even then you'll only spot it if you know exactly which 'star' among many it is.

NEPTUNE 04:00 BST on 15 July 2023



Constellation: Pisces **Magnitude:** +7.9 **AM/PM:** AM

Even when Neptune is positioned high in a dark sky this distant world needs a telescope to see it well, so during the start of our observing period, when it will be low in a light summer morning sky it will be hard to see. But by the middle of July it will be rising four hours before the Sun, before midnight in fact, so should be more visible.



MOON TOUR

LANGRENUS CRATER

This month, we help you find one of the Moon's best hidden gems

The Moon has many 'celebrity' craters, like Copernicus, Tycho and Eratosthenes, which are big and bright enough to be obvious to the naked eye. However, these celebrities owe their fame to a stroke of good fortune: the bodies that blasted them out of the lunar surface millennia ago struck the face of the Moon pointing right at Earth. There are other craters that are just as big and interesting as Copernicus, but they are reduced to B- or C-list status because they were blasted out of areas not so well-placed for observation. Instead, we see them at an angle, foreshortened by the curve of the Moon's limb. Langrenus is one such crater.

A 137-kilometre (85-mile) wide, six-kilometre (3.7-mile) deep hole, punched into the Moon by a massive asteroid impact millennia ago, Langrenus would rival great Copernicus in beauty if it had been formed near the centre of the Moon's face. Sadly, it was blasted out of the eastern edge of Mare Fecunditatis, the ancient sea directly to the south of the dark eye socket of Mare Crisium, and so Langrenus' beauty and apparent size are both greatly diminished, as it is almost on the Moon's limb.

Photographs taken by Apollo crews and lunar orbiters show that Langrenus is very similar in appearance to Copernicus when viewed from above: it is a roughly circular crater, with shallow walls that are more than 20 kilometres (12.4 miles) wide and broken up into more than half a dozen slumped terraces and ledges. The walls are especially rugged and rippled on its western side. Stark mountains jut up out of the crater's floor with three-kilometre (1.9-mile) high peaks that cast long, jagged shadows across the floor when sunlight hits them at a low angle after sunrise or before sunset. Beyond Langrenus's walls, out on the lunar plain, several rays of debris spread westwards from the crater, but again their appearance is diminished by the angle of viewing.

© NASA

TOP TIP!

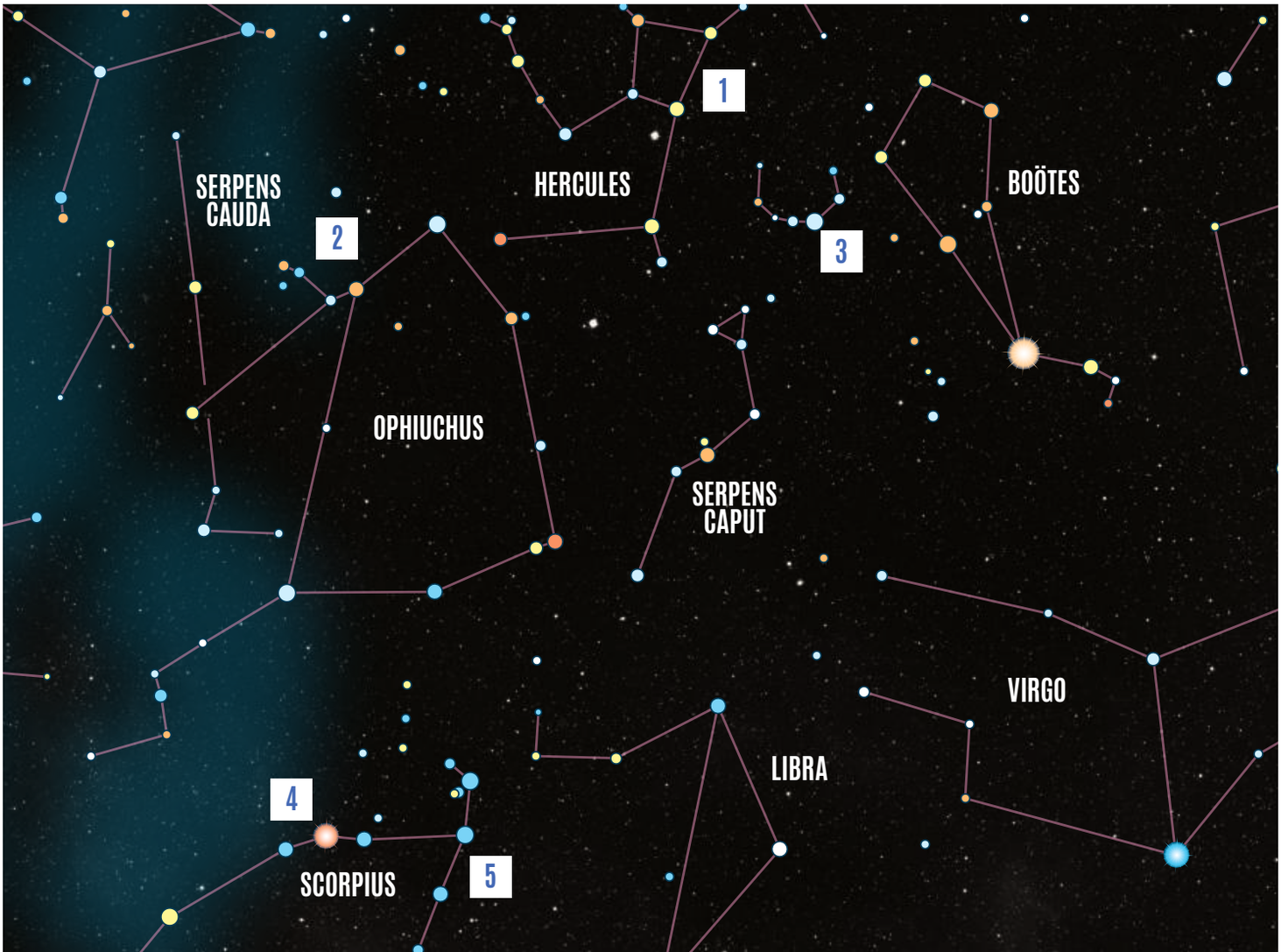
Look out for Langrenus during the first quarter Moon, where the crater appears as a small, bright oval shining close to the western limb.

One of the most striking things about Langrenus is the unusually high albedo – reflectivity, or brightness – of its floor. Its floor is very noticeably brighter than the surrounding terrain; it is more of a grey-white colour than the dark, ash-grey tones of the landscape around it. This means that although the crater is reduced to an oval or lozenge shape by foreshortening, it is at least a bright one and, unlike some craters, it is easy to see whenever sunlight is falling on it.

When bathed in sunlight, Langrenus is a small, bright oval shining near the western limb of the first quarter Moon, down at the 4 o'clock position on the Moon's face. Around full Moon – 3 July – Langrenus will be a very noticeable bright mark beneath Mare Crisium through binoculars, looking like a bright smash pattern left in an icy puddle after a stone has been thrown onto it.

The best nights to see the crater are on 5 and 6 July, when the Moon is starting to wane and the terminator begins to creep towards Langrenus from the west. With the Sun's rays slanting across the crater at a shallow angle, it will stand out from the surface and look more like a crater. View it through your telescope with medium to high magnification to see its central mountains and the shadows they cast across its floor. On 8 July, Langrenus is smothered by darkness and doesn't emerge until 22 July, when the Moon will be a beautiful, thin crescent. The crater will show some surface relief for the next few nights until its shadows are washed away by the rising Sun.

Langrenus is also known as a hot spot of 'transient lunar phenomena' – sudden brightenings that may be caused by releases of gas from beneath the crust – so keep an eye out this month.



NAKED EYE AND BINOCULAR TARGETS

The constellations of Hercules, Scorpius and Corona Borealis are ideal targets for those using binoculars or the unaided eye

1 Great Globular Cluster in Hercules (Messier 13)

Glowing at a magnitude of +5.8 and just about visible to the naked eye under excellent conditions, this stunning star cluster looks superb in binoculars with a magnitude of at least 10x50, where it appears more like a bright ball of unresolved stars.

2 Summer Beehive Cluster (IC 4665)

Just visible to the naked eye from very dark sites, this open cluster can be found in Ophiuchus. If you're looking to catch its member stars more closely, you'll need binoculars with a magnification of at least 10x50.

3 Corona Borealis

A small constellation with only a handful of stars visible to the naked eye, many astronomers have been inspired by the shape of Corona Borealis, which gives it the uncanny appearance of a crown. The brightest star in the pattern is Alpha Coronae Borealis, which shines at magnitude +2.2.

4 Messier 4

The tight-knit Messier 4 is easy to spot through good binoculars. Although visible to the naked eye under excellent night sky conditions, the globular cluster, which has a magnitude of +5.6, takes on the appearance of a fuzzy ball of light about the same size as the Moon.

5 The claws of the Scorpion

Three stars, Beta Scorpii, Delta Scorpii and Pi Scorpii, mark the claws of the celestial Scorpion. Roughly of second to third magnitude, these stars are visible to the naked eye under good observing conditions.

5 The Trifid Nebula (M20)

DEEP SKY CHALLENGE

NEBULAE AND CLUSTERS OF THE SUMMER

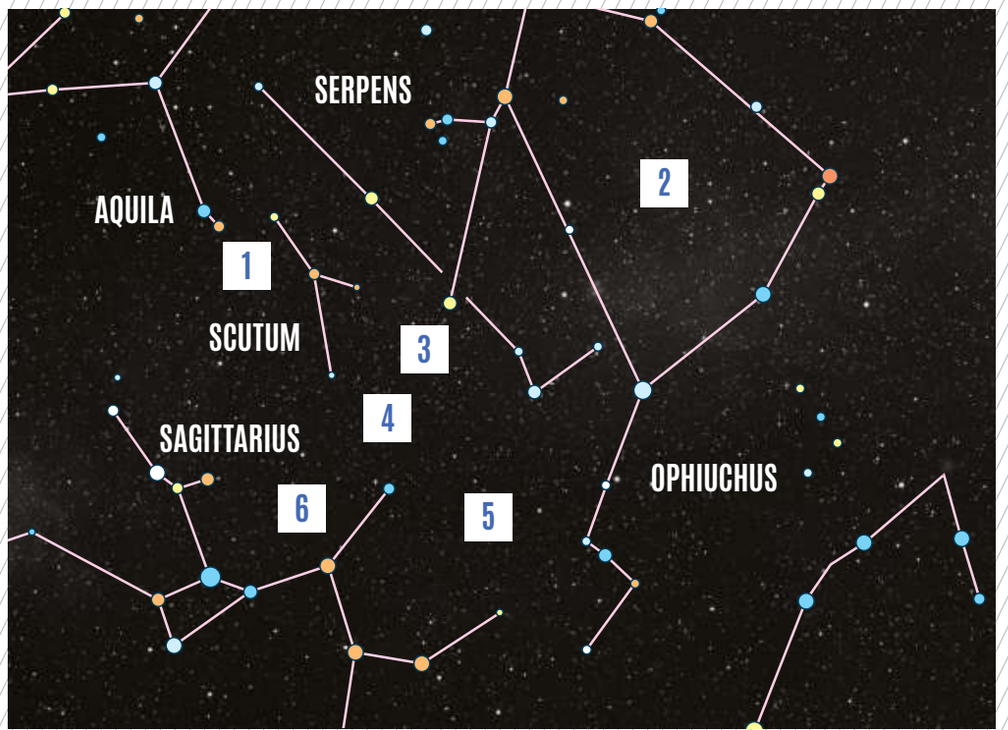
The nights are still short, but there are plenty of things to see if you're a night owl

It's well worth staying up late at this time of year, as some of the best and most spectacular targets for your telescope are well positioned in the night sky. For example, there's one of the best globular clusters in the entire night sky, as well as nebulae and open star clusters. The Milky Way sits on a line almost north to south, and some of the best objects can be found in the southern section, which you can go hunting for with your telescope.

No matter the size of your telescope, there will be some wondrous sights. Some of these objects are quite low down near the southern horizon, so try to find an observing spot that provides a good view in this direction with few trees or buildings along the horizon. Given that the nights in the Northern Hemisphere are usually relatively warm, there are plenty of reasons to get your telescope and enjoy what the universe has to offer. Here are some of the best objects to view...

1 Wild Duck Cluster (M11)

"Some of the best objects in the Milky Way can be found in the southern section"



1 Wild Duck Cluster (M11)
Taking its name from the 'V' shaped pattern of stars that looks like a flight of wild ducks, a small telescope will show Messier 11 well.

2 Globular star cluster M10
This tight globular star cluster is a target for telescopes of all sizes. Larger instruments should reveal many of the stars in the group.

3 Eagle Nebula (M16)
Made famous by the Hubble Space Telescope, this is a more challenging object. A larger telescope should show some detail.

4 Omega Nebula (M17)
This object has a distinct U-shape, so it's sometimes known as the Horseshoe Nebula. It is a huge cloud of hydrogen gas.

5 Trifid Nebula (M20)
The three dark dust lanes emanating from its centre give this nebula its name. It looks quite peculiar when viewed through a small telescope.

6 Globular star cluster M22
Due to its low declination, this star cluster looks fainter than usual. A moderate telescope should discern many of its stars and its bright

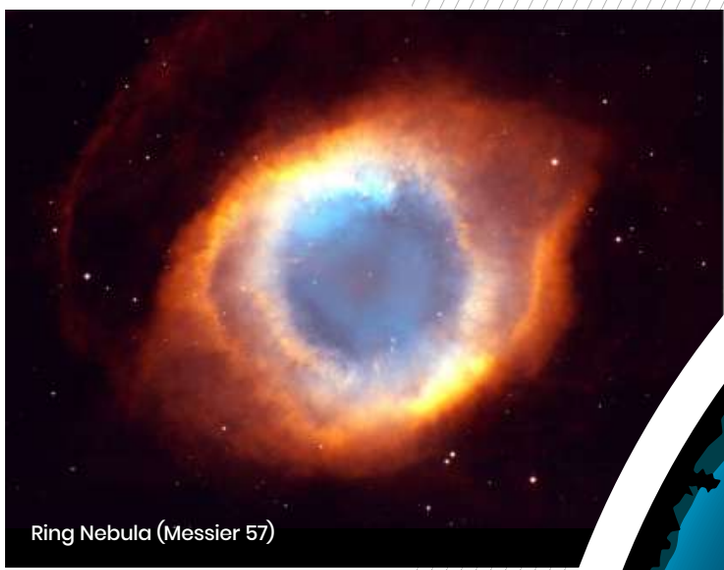
4 Omega Nebula (M17)

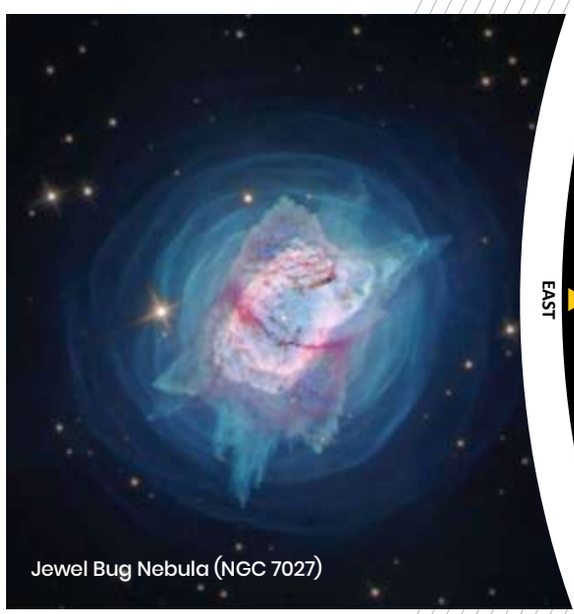
©: NASA, Hubble; ESA; Getty Images

NORTHERN HEMISPHERE

A gaggle of galaxies, star clusters and nebulae grace the July skies

There's an impressive array of targets suitable for observers armed with binoculars, telescopes or for those who are just content with gazing upon the night sky with the unaided eye. Galaxies and star clusters are abundant, but it's the nebulae within constellations such as Cygnus and Lyra that are the objects to look to this month. The Ring Nebula (Messier 57), the Pelican Nebula (IC 5070 and IC 5067), planetary nebula NGC 7027, reflection nebula NGC 6914 and the "Blinking Planetary" NGC 6826 are particularly impressive, providing observing and imaging opportunities.


Ring Nebula (Messier 57)


Jewel Bug Nebula (NGC 7027)

Omega Nebula (Messier 17)

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

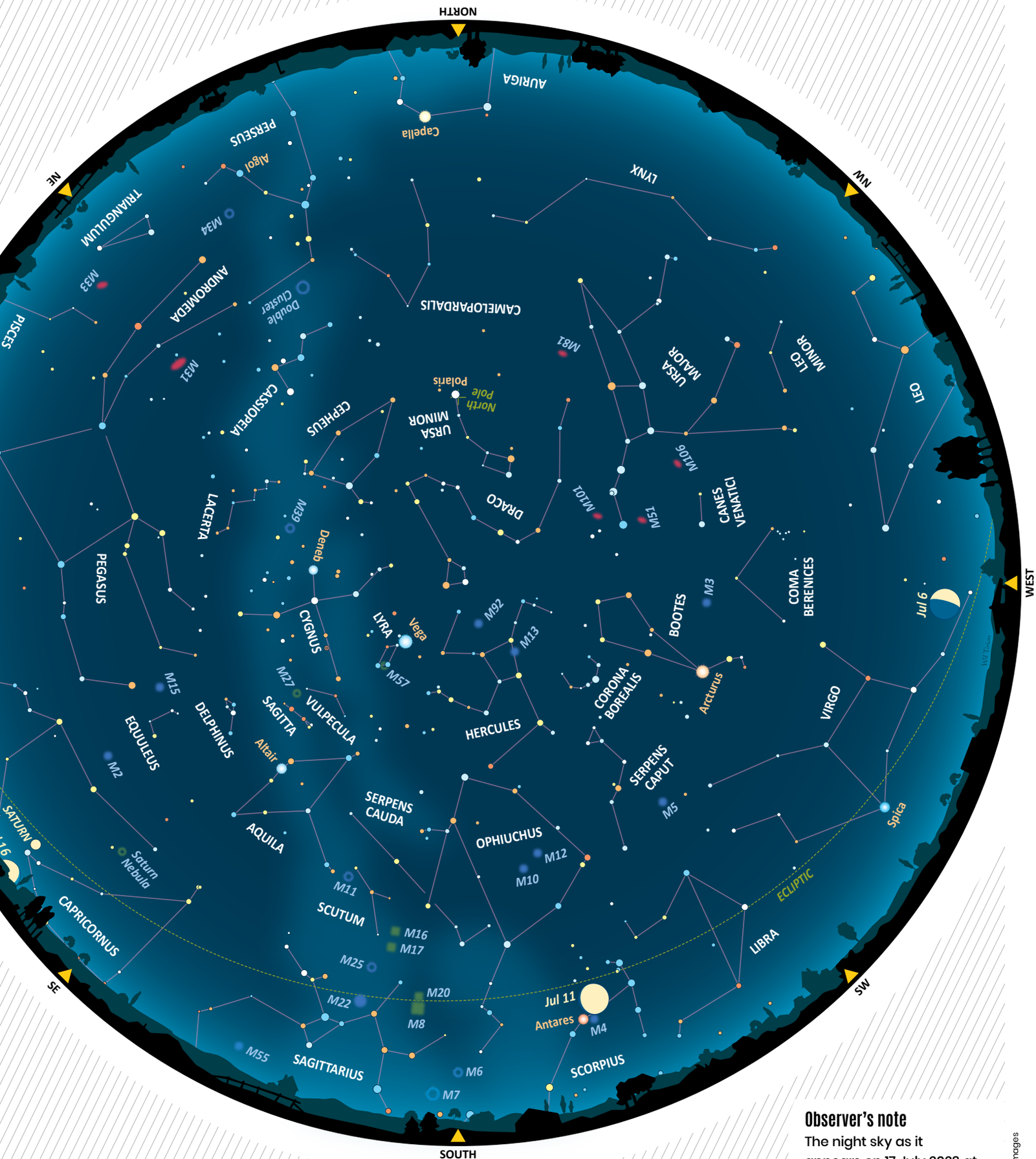
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O–B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note

The night sky as it appears on 17 July 2023 at approximately 22:00 (BST)

© Getty images

REVIEW

OLYMPUS 8X25 WP II

For casual skywatchers, the portable Olympus 8x25 WP II boasts an excellent optical system for views of the Moon and bright targets with superb contrast

Reviewed by Gemma Lavender

BINOCULAR ADVICE

Magnification: 8x

Objective lens diameter: 25mm

Angular field of view: 6.2 degrees

Eye relief: 15mm

Weight: 260 grams

ADDITIONAL KIT

- Carrying case
- Objective lens caps
- Neck strap
- Double eyepiece cover

Stylish and versatile, the Olympus 8x25 WP II binocular is built with the outdoor explorer in mind, featuring a nitrogen-filled fogproof and waterproof design that promises to breeze through even the most inclement weather. It is also lightweight and comfortable to hold thanks to a rubber-coated finish and weight of just 260 grams (9.2 oz). For even more ease of use while travelling, the Olympus 8x25 WP II can be folded away and slotted into the carry case. A neck strap is included for those needing to achieve magnified views without fumbling to unpack this piece of kit. A grooved central knob for focusing makes this a winner for observers wanting to just get viewing without any complications.

Most importantly, manufacturer Olympus boasts a BaK-4 porro prism design for their WP II model, and fully multi-coated lenses – the objectives of which are 25mm in diameter – for superb brightness, clarity and contrast whatever the observer chooses to magnify on their travels. Meanwhile, the eyepieces are protected with caps when not in use. We advise storing these caps in a safe place during your observations – without being tethered to the Olympus 8x25 WP II, they are easy to lose!

Out of the box, the Olympus 8x25 WP II certainly lives up to the hype – this piece of kit is a delight to hold. They may be light – our arms didn't get tired when sweeping across the night sky for a good five minutes at a time – but manufacturer Olympus hasn't skimped on the quality. No part of the housing felt flimsy to the touch, promising to last for many observing sessions to come, whatever the conditions.

Housing of the binocular is of an excellent quality, designed to last for many observing sessions

BEST FOR...

- MEDIUM BUDGETS
- CASUAL ASTRONOMERS
- LUNAR OBSERVING
- BRIGHT DEEP-SKY TARGETS
- PLANETARY OBSERVING

The binoculars are waterproof and fogproof thanks to nitrogen-filled housing

The optics are fully multi-coated for great brightness, contrast and clarity

March proved to be dogged with poor weather, with many a rain shower as we moved into April. While observations of a selection of targets was off the cards for several nights, we took the opportunity to test how waterproof the Olympus 8x25 WP II is. Grabbing a waterproof coat before preparing the binoculars for observation, we headed outside to a torrential downpour. Visibility was poor and we braced ourselves against a cooler temperature of 6 degrees Celsius. With aggressive winds buffeting us from the south, we were forced to take shelter against a wall while training the binoculars on a lamp post. Except for a few stray raindrops falling onto the objective lenses, which we quickly wiped away with our microfibre cloth, the Olympus 8x25 WP II was not affected by the terrible conditions – no leaking into the housing was detected and the optics performed with ease, with the nitrogen-filling keeping our field of view free of fog as we periodically migrated to and from the warmth of the indoors.

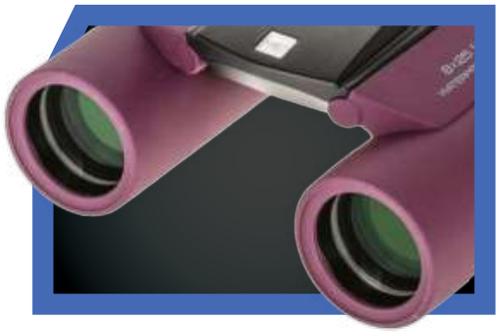
We took ourselves out of the lashing rain and wind to study the eye relief of the Olympus 8x25 WP II. Boasting a decent 15mm, we put spectacles on to appreciate the generosity of the eyecups, which can be twisted out when the binoculars are in use. We are even further delighted with the lack of fiddliness of the eye shield feature: since with some models of binocular, we have been forced to fold the rubber eyecups back to achieve comfortable views.

"Out of the box, the Olympus 8x25 WP II certainly lives up to the hype – this piece of kit is a delight to hold"

In the way of supplied accessories, the lens caps fit snuggly for a protective fit, while the neck strap could be adjusted with ease. A slight niggle is that the material of the strap could have been better; after some time it felt rough against the skin, so we advise either upgrading to a padded option or putting the collar of your coat in between the back of your neck and the material. Overall though, we had no concerns with its ability to support the binoculars' weight. Drying them after our final venture into the outdoors, we waited for a few evenings before it was clear enough to test the mettle of the Olympus 8x25 WP II's optical system.

The manufacturer specifications promise a field of view of 108m at 1000m, an actual field of view of 6.2 degrees, and an apparent field of view of 49.5 degrees. With a magnification of 8x and aperture of 25mm, the Olympus 8x25 WP II isn't necessarily a skywatcher's first choice for observing the night sky, but we were optimistic, especially when it came to viewing the brighter, easy-to-access solar system and deep-sky targets with magnitudes of at least +4.0.

A waning gibbous moon with 17 per cent illumination is easy pickings for the Olympus 8x25 WP II, and we were delighted with how much more we could see, and comfortably, compared to the unaided eye. To give a feel of what is visible through the eyepieces, the binoculars' angular field of view is 6.2 degrees and, with a full moon having an angular size of roughly half a degree, the view is able to fit 12 full Moon widths. This means that views are small, but we could still appreciate the detail and clarity of our chosen target. Our eyes skimmed the lunar mare Oceanus Procellarum (Ocean of Storms), before sweeping along the terminator to take in the rugged terrain. The binocular afforded us the opportunity to spot small and clear sights of craters Kepler, Grimaldi and Byrgius with ease. No defects in the optical system, such as colour-fringing is visible along the Moon's limb and the



contrast and clarity is seamless for an excellent proportion of the field of view.

Dazzling at magnitude -4.1, we headed west to take in the second planet from the Sun, Venus. Admittedly, the views weren't massively breathtaking due to the planet's largely featureless disk. However, we did enjoy the magnified view of the fierce luminosity through the binoculars' optical system. The constellation of Orion the Hunter could be caught before it dipped below the south-western horizon, and we were rewarded with a plethora of stellar targets. The fuzzy glow of the +4.0-magnitude Orion Nebula (Messier 42), with a few members of the Trapezium Cluster at its heart, could be observed with beautiful contrast and clarity, while Orion's Belt was visible in the same field of view.

Lazily sweeping the heavens with the Olympus 8x25 WP II as the night sky continued to get darker, we were treated to sections of sky, populated with further faint stars, offering more to see over naked eye viewing, especially in slightly light-polluted conditions. The nitrogen-filled design continued to perform at its best, with no water of fogging hindering our views. Given the small aperture of the objective lenses, the Olympus 8x25 WP II aren't able to gather much light, which hinders the ability to see far-flung galaxies and some of the fainter nebulas of magnitudes dimmer than +6.0. Despite this, they deliver pleasing views of superb colour fidelity, provided you're mindful of the binoculars' capabilities.

The functionality of the Olympus 8x25 WP II is pleasing. The focusing wheel turns smoothly, enabling our targets to be brought into clear focus, while small movements could also be made for higher accuracy in achieving sharper views. The twistable eyecups were a delight, with no sticking or exertion required in pulling them out for observing. They folded in just as neatly when it was time to pack the binoculars away.

We consider the Olympus 8x25 WP II as an all-arounder for those looking to dabble in a range of observing. However, it's important to note that due to its small aperture, it isn't suited to dedicated skywatching, particularly when fainter targets are concerned. We recommend looking for binoculars of at least 10x50 magnification and aperture, with some respected models – including those from Celestron, Nikon, Orion and Helios – being found reasonably priced at trustworthy stockists.

If you're keen to add the Olympus 8x25 WP II to your arsenal, we recommend it as a companion for wildlife enthusiasts and for those who love trekking, while also taking in the views of their surroundings. We experienced a very good optical system that offers fair to good views of some night sky targets – however, the binoculars are best suited to casual skywatchers. Be warned: if you are an astronomer who is serious about taking your observations to the next level, you will find yourself upgrading on the Olympus 8x25 WP II within a year.

Externally, the binoculars don't fail to impress: the build is superb, with no cheaply made parts. The barrels are comfortable to hold, while the lightweight design ensured that our arms weren't aching and shaking as we toured our surroundings. The neck strap could do with an upgrade, and users should be aware that the lens caps are easy to lose since they aren't attached to the binocular's barrels.

The Olympus 8x25 WP II features twistable eyecups for a generous eye relief of 15mm

FOR

- ⊕ Excellent, high-quality build
- ⊕ Water and fog proof
- ⊕ Decent eye relief
- ⊕ Very good contrast and superb clarity
- ⊕ Lightweight for long, steady observing sessions

AGAINST

- ⊖ Neck strap needs upgrading
- ⊖ Low light-gathering prowess
- ⊖ Expensive compared to binoculars more suited for skywatching

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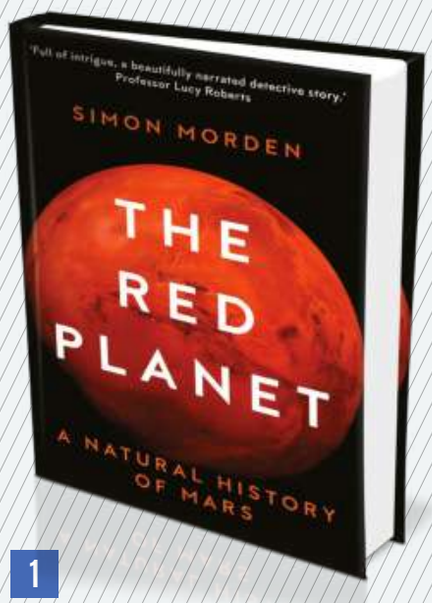
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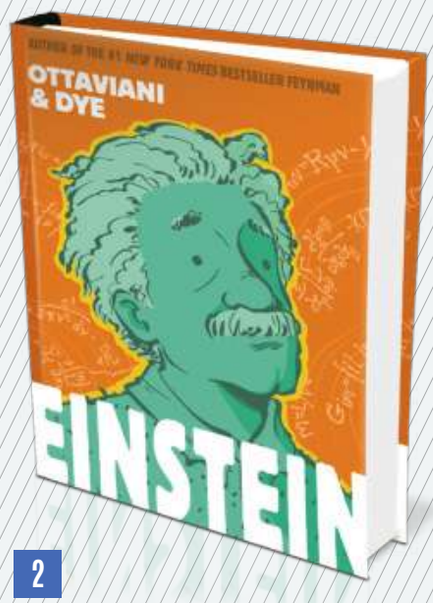

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The Red Planet

Cost: £9.99 / $17.30
Publisher: Elliot & Thompson

1 Planetary geologist and geophysicist Dr Simon Morden is a writer who has won the prestigious Philip K. Dick Memorial Award for his fiction, and naturally he's a science fact writer too. His new book *The Red Planet* is a truly experiential journey through time and across the surface of Mars.

It's split into a loose chronology of the history of Mars, from its formation through to the present day and into the future, detailing its many mysteries that still baffle us today.

For all his credentials as a scientist, it's Dr Morden's pedigree as a sci-fi author that sets *The Red Planet* apart from the myriad of other tomes on the natural history of Mars. He switches much of the heavy terminology out for metaphor, stitching sections together with an easy, flowing narrative. It's as much about imagination and artistic licence as it is established fact and expert opinion, so step aside dry textbooks and jargon-stuffed research papers, *The Red Planet* is a benchmark in space literature.

Einstein

Cost: £23.99 / $29.60
Publisher: Roaring Brook Press

2 Meet the man that changed the way we view the universe and follow his journey through life, love and science. *Einstein* isn't your typical biography. Rather than flicking through pages of text and constructing a person's life with your imagination, the story of Albert Einstein is told through illustration as a graphic novel. As the story evolves from Einstein's early days in the late 1800s up to his death in 1955, illustrator Jerel Dye brings the physicist's world to life through his incredibly detailed artwork. For his contribution to science, Einstein's name is now synonymous with genius but his personal life is less well-known. This book takes a look at the life behind the brilliance in a continual narrative, jumping between distinct milestones and achievements. *Einstein* is an excellent way to introduce a teenage audience to one of the world's greatest minds. It's much longer than your average graphic novel and at nearly 300 pages, it's one to sit down with and really get your teeth stuck into.

Space 2069

Cost: £16.99 / $22.00
Publisher: Icon Books Ltd

3 In 1969, humans first walked on the Moon. Now, halfway towards Apollo 11's 100-year anniversary, this is the best time to track how much space exploration has evolved since, and to analyse the progress that is likely to be made by 2069. Astronomer Dr David Whitehouse has done just that, combining the history of space travel with his expert knowledge to predict the next 50 years.

Whitehouse takes you on a three-part journey. The first outlines the importance and plans for the 2024 mission that will take us back to the Moon. The second tackles the hardships that may be faced in safely placing people on Mars and utilising space tourism. The third section explores beyond what is planned. How far will space travel take us? And where are our limits? The final chapters will set your imagination rocketing. *Space 2069* is ideal for all space enthusiasts who want to learn more about significant past missions, the true possibilities and the hurdles that will stand before our future goals.

"It'll certainly give amateur astronomers and space fans a broader perspective of the cosmos"

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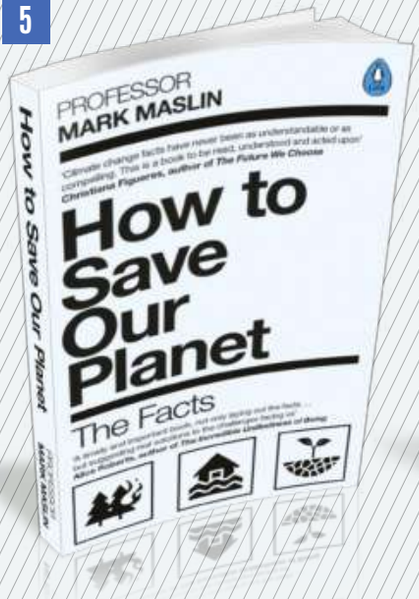
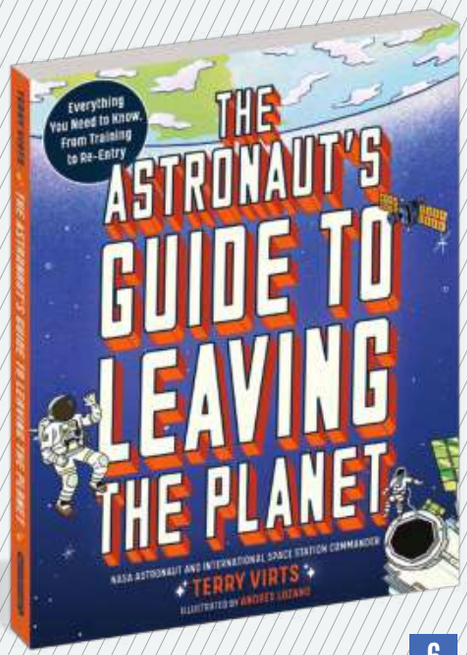




6

A History of the Universe in 21 Stars (and 3 imposters)

Cost: £12.99 / $14.95
Publisher: Welbeck

4 How did astronomer and author Giles Sparrow choose 21 (+3) from the billions of stars (and imposters) in our galaxy, to put on his literary catwalk? Fortunately we can describe the life cycle of entire groups of stars just by looking at one example: Sparrow highlights the bright orange giant Aldebaran as a K-type star whose colour tells us a lot about its age, temperature and a myriad of other stellar characteristics. He talks about the history of Aldebaran's observation from Earth that, given it's one of the brightest and most distinctive stars in our sky, goes back thousands of years. It's a simple and very effective format for describing our universe, and this is a book that's very well-written and fairly accessible to anyone who has a good general awareness of space topics. It'll certainly give amateur astronomers and space fans a broader perspective of the cosmos.

How to Save Our Planet

Cost: £7.99 / $9.90
Publisher: Penguin Books Ltd

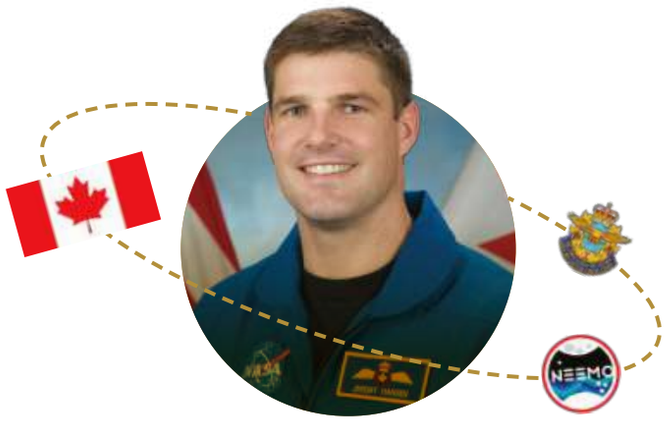
5 As a frank and relevant book on climate change, *How to Save Our Planet* strips away the soft, cushioning language about the state of our climate and presents blunt facts about how we got to where we are and how we could prevent further problems. This book is a refreshing read when it comes to talking about climate change and the environment. If you ever find yourself in a verbal tussle with a climate change denier, this is the book you need in your back pocket. It's jam-packed with quotable figures and stark statistics that would inform discussions not only around a pub table but across the aisle in parliament. The author outlines the political and economical changes that need to be made by governments around the world to tackle climate change, and predicts that "The challenge of the 21st century is that we must learn to think and act as a global species".

The Astronaut's Guide to Leaving the Planet

Cost: £12 / $14.99
Publisher: Workman Publishing Co.

6 Did you want to be an astronaut when you were younger? Or have you just always wondered what it's like in space? This book is written by former NASA astronaut Terry Virts, providing real facts and from first-hand experience. *The Astronaut's Guide to Leaving the Planet* covers historic space travel missions, the types of training involved, how astronauts live and work in space and top tips for the future generations of astronauts. Much of this guide covers the general science and technology of space travel, but it also includes personal views, opinions and memories of being in space.

There is a combination of awe-inspiring real photographs and creative illustrations that capture life in space with accuracy and vibrance. After absorbing the insight from this book, young readers will feel ready to explore the complex and exciting environments of space that await them.



JEREMY HANSEN

The first non-American to leave low Earth orbit on Moon mission Artemis 2

Hansen was born on 27 January 1976, and grew up in two towns near London, Ontario, a city west of Toronto. His work in aerospace began at the tender age of 12 when he joined the 614 Royal Canadian Air Cadet Squadron of London. Hansen earned his Air Cadet glider wings at age 16 and then a year later, at age 17 in 1992, received his private pilot licence and was accepted to the Royal Military College Saint-Jean in Quebec. By 1994, thanks to "the discipline and self-confidence" Air Cadets gave Hansen, he was accepted for officer training in the Canadian Armed Forces.

After completing basic training, Hansen began a four-year bachelor's degree in space science at the Royal Military College. He completed CF-18 fighter pilot training in 2003. Hansen then served as a fighter pilot between 2004 and 2009, with 441 Tactical Fighter Squadron and 409 Tactical Fighter Squadron; he also was Combat Operations Officer at 4 Wing Operations.

Hansen was recruited to the CSA after the 2008-09 recruitment campaign that selected two astronauts among 5,350 applicants, the agency stated. Selected alongside Hansen was David Saint-Jacques, who eventually received an International Space Station mission in 2018 to 2019.

The duo graduated from basic astronaut training in 2011, alongside the 2009 NASA astronaut class. Hansen was assigned to capcom duties in Mission Control as well as ongoing mission support. Hansen also increased his remote environment experience for simulating spaceflight. For example, he was a crew member in the European Space Agency's Cooperative Adventure for Valuing and Exercising human behaviour and performance Skills (CAVES) program in a cave complex in Sardinia in 2013. He also served with NASA Extreme Environment Mission Operations (NEEMO) 19, which worked underwater in 2014. Canada's contribution to the ISS is modest. The Canadarm2 used for servicing the ISS and berthing spacecraft is Canada's contribution to the consortium and allowed for flights approximately every six years.

Hansen, therefore, did not fly for a while, as two-time astronaut Chris Hadfield was assigned to an ISS mission in 2012-13 and Saint-Jacques then received his 2018-19 flight. But Hansen picked up significant ground responsibilities in the meantime.

Hansen was assigned as the schedule manager for the 2017 astronaut class, acting as a mentor and training coordinator alike. Behind the scenes, Hansen also worked closely with top Canadian policy-makers. The mission specialist aboard Artemis 2, he is expected to start his ten-day mission in November 2024. Flying with Hansen on the Moon mission will be three NASA astronauts: commander Reid Wiseman, pilot Victor Glover and mission specialist Christina Koch.

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